



Title	High-Tech Pollution
Author(s)	YOSHIDA, Fumikazu
Citation	ECONOMIC JOURNAL OF HOKKAIDO UNIVERSITY, 23, 73-138
Issue Date	1994
Doc URL	http://hdl.handle.net/2115/30514
Type	bulletin (article)
File Information	23_P73-138.pdf



[Instructions for use](#)

High-Tech Pollution*

Fumikazu YOSHIDA

This is a comparative study of high-tech pollution in USA and Japan. High-tech pollution is a new type of environmental damages caused by high-tech industries:

1. First of all, "clean" means only "without dust," and the object is to keep "clean" the materials and parts used for making semiconductors. But the "cleanness" of its operatives and the environment which surrounds semiconductor factories is another thing. 2. Apart from the apparent waste of water, the waste of gases, the industrial waste and garbage which have been the focus of environmental concern till now, leakages from "storage" tanks of used solvents is a principal cause of pollution. 3. Besides rivers and the air, therefore, groundwater plays an important role as a route for pollution. 4. The semiconductor industry uses many sorts of toxic chemical, gases & radioactive rays, which have, even in a very small quantity, the potential of causing complex chemical pollution. 5. Because high-technology changes very fast and secrecy prevails in this field, corresponding environmental protection tends not to be forestalled.

Contents

1. "A New Type of Pollution" — The Fairchild Case —
2. A warning from Silicon Valley
 2. 1. An "Advanced Area" of High-Tech Pollution
 2. 2. Serious Groundwater Pollution
 2. 3. The Danger of Silicon Valley
 2. 4. Occupational Safety Problems
3. Tackling the Cleanup
 3. 1. The Environmental Protection Movement in the USA
 3. 2. Conduct of Government
 3. 3. Tackling Cleanup by Businesses
 3. 4. What can we learn from Silicon Valley?
4. The Real Semiconductor Industry

* This is a revised edition of *High-Tech Pollution* (Tokyo, Iwanami Shoten Publisher, 1989), [In Japanese].

4. 1. The Characteristics of the Semiconductor Industry
4. 2. Relationship between High-Tech and Environmental Problems
4. 3. The Material Balance of A Semiconductor Plant
4. 4. Organic Solvent
4. 5. Problems of Organic Solvent
4. 6. Problems of CFCs
4. 7. Toxic Gas
4. 8. Gallium Arsenide
4. 9. Economic Aspects of High-Tech Pollution
5. High-Tech Pollution in Japan
 5. 1. Groundwater Pollution by Toshiba Components, Kimitsu
 5. 2. Nationwide Groundwater Pollution in Japan
 5. 3. Toshiba, Taishi Plant—The First Example of High-Tech Pollution—
 5. 4. Groundwater Pollution in Kumamoto —A Critical Situation—
 5. 5. Miyazaki City Municipal Water Source is Located near the Drainage Outlets of Two Semiconductor Plants
 5. 6. Groundwater Pollution along the Tama River
6. How to Protect Our Environment
 6. 1. Legal Regulation of Chemicals
 6. 2. An Agreement for Environmental Protection which Requires Manufacturers to Submit Names of All Chemicals Used
—Kitakami City and Iwate-Toshiba-Electronics—
 6. 3. An Agreement for Environmental Protection Including a “Closed Drainage System” and “Toxic Gas Regulation”
—Tateyama City and NMB (Nittetsu) Semiconductor—
 6. 4. To Forestall High-Tech Pollution

1. “A New Type of Pollution”

— The Fairchild Case —

Rick Puppo is a gardener who lives in Los Paseos, San Jose, California. When I visited him one evening, he was watching a baseball game on TV with his sons. His family is typically American. On the table, however, was a small bottle of heart disease tablets, which his younger son, Brian, has to take every day.

The story goes back to the end of 1980, when it was discovered that newly-born Brian had a hole in his heart. Brian had to have an operation only one and a half months after his birth. This was followed by three more operations and he was hospitalized for six months. Only when Rick Puppo read a local newspaper article did he realise that in Los Paseos many children had been born with heart defects.

The Fairchild underground storage tanks of used organic solvent had leaked and contaminated well #13, which supplied the neighborhood's water. According to the victims' map prepared by the citizens and their attorney, the victims were scattered widely. Red flags represented heart diseases, blue flags showed miscarriages, yellow flags signified cancer and black flags meant deaths.

In April, 1982, therefore, the victims brought a suit against Fairchild, IBM and the Great Oaks Water Company. The number of citizens involved rose to about 530.

The problem focuses on the link between the contamination from the Fairchild well and the harm suffered by the victims. Even according to the calculations of Fairchild itself, from April, 1977, to December, 1981, about 58,000 gallons of 1, 1, 1-trichloroethane (organic solvent) were lost. Stirred into action by the demands of the citizens, the California Department of Health Services carried out an epidemiological study. The study, named *Pregnancy Outcomes in Santa Clara County 1980-1982*, consisted of two parts. The first part compared rates of cardiac defect in the area served by the Great Oaks Water Company with the rates in the rest of the county. The second study investigated the number of cases of spontaneous abortion and congenital anomaly. According to the

Fig. 1 Fairchild Camera & Instrument San Jose Site

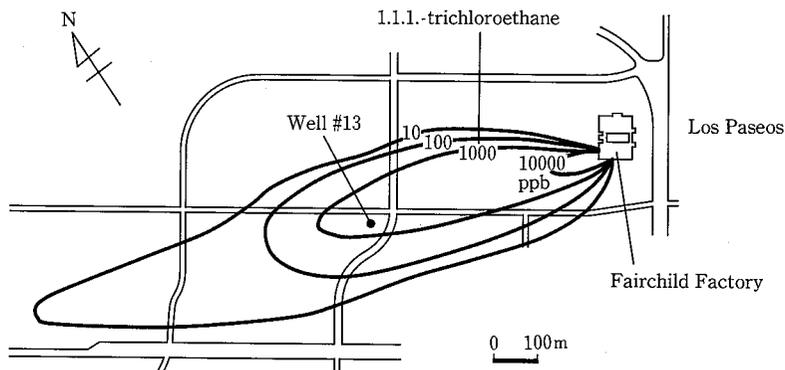


Table 1. Pregnancy Outcomes in the Los Paseos Area, 1980-1981
(California Department of Health Services, January 1985)

	Miscarriage	Malformation*	Deformation**
Number	41	10	3
Rate	21.5%	6.9%	2.1%
Control Area	11.0%	2.2%	0.6%

* Nasolacrimal stenosis, Ventricular septal defect, Low set ears, Benign form of webbed toes, Omphalocele equinovarus, Total anomalous pulmonary venous return, Imperforate anus & kidney anomaly, Down's syndrome, Congenital diaphragmatic hernia, Cleft lip and palate

** Left club foot, Internal tibial torsion, Right talipes equinovarus

first study, in 1981 ten babies with major cardiac defects were born to residents of this district. This represents an excess of six cases over the expected number. But the solvent leak is in itself an unlikely explanation for this excess.

The second part gave details of various defective birth rates; the spontaneous abortion rate among pregnant women (Los Paseos 21.5%, control area 11.0%); the congenital malformation rate (Los Paseos 6.9%, control area 2.2%); the congenital deformation rate (Los Paseos 2.1%, control area 0.6%). The investigators concluded, however, that the indirect evidence of the extent and timing of exposure to contaminated water within the Los Paseos area was insufficient to determine whether the leak of chemicals into well #13 had caused the excessive rates.

The California Department of Health obviously avoided making a definite statement. According, though, to the testimony at the hearing in Congress of the person in charge, Dr. S. Swan, the rates of alcohol consumption, smoking, occupation were not responsible for the differences in the rates of the diseases noted. A new report was subsequently released in March, 1986; it announced that from January to June, 1983,

1. 69 babies were born to mothers living in Los Paseos. None suffered from birth defects.
2. In the entire Great Oaks service area 15 of 605 babies had congenital defects. This figure gave the area a birth defect rate of 24.8 per thousand live births, the same number as reported for the whole of the Santa Clara Valley and the San Francisco Bay Area put together.

At the same time, a group at the New Jersey Medical School found a relationship between 1, 1, 1-trichloroethane exposure and the appearance of cardiovascular abnormalities in rats.

Against this background, in July, 1986, Fairchild, IBM and the Great Oaks Water Company agreed to pay a "multimillion dollar" settlement to 530 residents. Attorneys and others on both sides of the suit, however, refused to reveal the specific terms of the settlement (*San Jose Mercury News*, July 4, 1986).

This appeared to mean that the Fairchild case was now closed. In May, 1988, however, a further report named *Pregnancy Outcomes in Santa Clara County 1980-1985*, produced by the California Department of Health Services ruled out 1, 1, 1-trichloroethane as a cause of the miscarriages and birth defects because residents of an adjoining neighborhood were not similarly affected, even though they had received more of the contaminated water than had Los Paseos residents.

In the nature of things, the victims and their attorneys are very critical of this report. They have pointed out that there has been no health damage since

the closing of well #13. They claim that the link is clear and that the case has already been settled. If I reexamine the final report, for example, I find that the malformation rate (1980, 1981) for the adjoining neighborhood and Los Paseos is 6.0%, whereas that for the unaffected area is 2.2%. In 1982-1985, however, the rate of 6.0% decreased to 2.9%. The report contains no analysis of this phenomenon. With regard to the way in which one may be exposed to the solvent, we have to pay attention to a new theory that stresses the part played by taking a shower or washing one's hands in addition to the drinking of the water itself. In Tucson, Arizona, a new study carried out by the University of Arizona Health Science Center found 2.5 times more cases of heart defect in babies born to people exposed to solvent, trichloroethylene contaminated wells near an Air Force base and Hughes Aircraft Company, compared with babies born to unexposed individuals.

In Woburn, Massachusetts, a group from the Harvard School of Public Health found a positive statistical association between access to water contaminated with chlorinated organics and the incidence rates of childhood leukemia. It also reported that damage to the immunological system was manifest since there were altered ratios of T lymphocyte subpopulations.

To sum up, the Fairchild case highlights the problems of a "New Type of Pollution", because 1, High-technology industries which seem to be clean are not always clean; 2, The leak of underground solvent tanks caused pollution of groundwater; 3, Organic solvents such as 1, 1, 1-trichloroethane and trichloroethylene, which create occupational safety problems within a factory, are the main pollutants.

2. A Warning from Silicon Valley

2.1. An "Advanced Area" of High-Tech Pollution

Silicon Valley

Today, "Silicon Valley" has become a metonymic synonym for any high-technology industrial region. Silicon Valley is the name first given to Santa Clara Valley, Santa Clara County, lying at the southern tip of San Francisco Bay.

Santa Clara County includes Palo Alto at its northern limit and San Jose at its southern end. About 1.47 million people live in this area, while roughly 2,900 high-technology related companies employ about 230,000 personnel.

After World War II, many computer and electronics companies such as Shockley Transistor, Fairchild Semiconductor and its spin-off companies (Intel, AMD etc.) moved into this area. Without Silicon Valley, we cannot imagine the postwar development of the American semiconductor and electronics industries. In Santa Clara County alone, these two main industries are responsible for 25%

of all U.S. production of semiconductor & related devices, and for guided missiles & space vehicles. Silicon Valley has about 178 semiconductor factories (including wafer manufacturing in 1990), of which 40(22%) employ 250 or more people, 52(29%) employ between 50 and 249 people, and 86(48%) employ fewer than 50 people.

This high percentage of small-scale semiconductor companies is the chief characteristic of Silicon Valley. The rapid growth of population in this area has led to a shortage of housing and inflation in its price, congestion of traffic and a high rate of divorce. Along with these problems, high-tech pollution has added to the difficulties.

As for the labour force, the percentage of professionals is relatively high — 30%. On the other hand, however, the female operatives in printed circuit board manufacturing, for example, are drawn from minority ethnic groups. Hispanics live in the eastern part of San Jose, Vietnamese live near central San Jose. This is the unknown side of Silicon Valley.

What is High-Tech Pollution ?

When I visit Silicon Valley in the daytime, I cannot understand why it is called a “valley”. Only when the smog thins out toward evening, and the surrounding mountains appear, can I understand that this area really is a “valley”. Such pollution, however, is only the tip of the iceberg of the environmental deterioration of Silicon Valley. High-technology attracts enthusiastic attention from all quarters as a leading force of the new industrial society, yet, as the example of Silicon Valley shows, people have gradually come to realise that high-technology, in contrast to its clean image, imposes a heavy burden upon the environment. What are the features of high-technology (here, I focus mainly on the electronics industry and its associates) that relate to these new environmental problems?

1. First of all, “clean” means only “without dust”, and the object is to keep “clean” the materials and parts used for making semiconductors. But the “cleanness” of its operatives and the environment which surrounds semiconductor factories is another thing.
2. Apart from the apparent waste of water, the waste of gases, the industrial waste and garbage which have been the focus of environmental concern until now, leakages from “storage” tanks of used solvents is another major cause of pollution.
3. Besides rivers and the air, therefore, groundwater plays an important role as a route for pollution.
4. The semiconductor industry uses many sorts of toxic chemical, gases &

radioactive rays, which have, even in a very small quantity, the potential of causing complex chemical pollution.

5. Because high-technology changes very fast and secrecy prevails in this field, corresponding environmental protection tends not to be forestalled.

Silicon Valley offers a good example of how "High-Technology" not only tends to concentrate in one area but also of how it pollutes that area. That is because,

1. Silicon Valley itself is a highly concentrated area of high-technology industries with about 2,900 high-technology companies, and about 230,000 employees, all within a radius of 12 miles ;
2. There is the danger of "double exposure": a), health injury caused by high-tech related pollution, and b), occupational exposure to toxic chemicals ;
3. In Silicon Valley, there has been extensive and concentrated water pollution, and much money and time is required to reverse it ;
4. A strong anti-pollution civil movement has grown up and an earnest effort to tackle high-tech pollution has grown up and an earnest effort to tackle high-tech pollution has been made by local government and the companies themselves.

As a last resort to vitalise local economies, high-technology industries are now expected to move in from all quarters. To forestall a possible "New Type of Pollution", I would like in this chapter to analyse comprehensively the high-tech pollution of Silicon Valley, based on my field research, and urge that we should listen most carefully to the warning from Silicon Valley.

2.2. Serious Groundwater Pollution

The Extent of High-Tech Pollution

As I have stated in Chapter 1, the Fairchild case spurred a complete investigation of the leakages from groundwater tanks and of the extent of groundwater pollution in Silicon Valley. This investigation found that pollution is alarmingly extensive. From the data gathered by the "Silicon Valley Toxics Coalition", I would like to offer a picture of the present state of pollution in Silicon Valley.

1. 80% of high-risk underground solvent tanks have leaked.
2. About 100 toxic chemicals have been detected in the groundwater.
3. In Santa Clara County, more than 150 leaks from underground tanks have been detected and over 200 public and private wells have been contaminated.
4. Santa Clara County has 23 U. S. EPA (Environmental Protection Agency)

Superfund sites (extremely contaminated sites where special federal or state funds are used for the cleanup), more than in any other county.

5. 100,000 tons per year of toxic waste are produced in Santa Clara County and 8.5 million pounds of toxic waste are discharged into the environment.
6. The San Francisco South Bay discharge of 30,000 to 120,000 pounds per year of toxic metals (including silver, copper, cadmium and nickel) from Silicon Valley is causing serious environmental damage to the wetlands.

Groundwater Pollution in Silicon Valley

Since people in Silicon Valley take about half of their drinking water from underground sources, its pollution is extremely serious. In October, 1981, leakage of organic solvent 1,1,1-trichloroethane from an underground tank was first detected at IBM. IBM used the solvent for the cleaning of magnetic disk drive parts, and reported the leakage to the local government authority, which, however, did not take it seriously. If they had investigated thoroughly at the time, it would have been possible to have found the route of the pollution and, therefore, to have stopped its expansion. Pollution has already extended into a 500 foot deep-well. Then in December, 1981, the Fairchild Camera and Instrument Company reported that it had lost a significant amount of 1,1,1-trichloroethane; a week later, large amounts of 1,1,1-trichloroethane showed up in the Great Oaks Water Company well #13, 2,000 feet away. The well water was contaminated with 5800 ppb 1,1,1-trichloroethane, 29 times the maximum recommended contaminant level set by the EPA. The President of the Great Oaks Water Company, Betty Roeder, admitted that waiting to tell the public about the pollution of well #13 had been a big mistake. She also admitted that the storm drain water from well #13 into Canoas Creek had seeped back underground and had most likely contaminated a well field of the San Jose Water Company. At the same time, she complained that she had never received any help from the California Department of Health Services.

As the investigation progressed, between 1981 and 1982, 21 more leakages from tanks were found, and up till April, 1984, 71 leakage points had been reported. Since there had been so much leakage from underground tanks and resultant well contamination, we have to conclude that these phenomena did not occur by accident. Why are there so many underground tanks and why are they so poorly made? Chemical tanks — like gasoline tanks — are located underground because the local fire and architecture ordinances compel companies to put them there. Owners have been happy to obey the ordinance to preserve the attractiveness of the site.

“Bury it and forget it. A Fiberglass fuel tank won’t corrode.” This is an advertisement for a fiberglass fuel tank; it stresses “Long life”, “Savings” and

"Fewer Worries". The problem is that many underground tanks were made of sorts of fiberglass which are not only likely to "corrode" but also to crack under uneven ground pressure.

According to the EPA survey of 1986, of 2,500 cases of underground tank release in the USA, about 50% of the leakages were caused by structural failure, while about 30% were the result of corrosion. In Silicon Valley, 80% of the underground solvent tanks have leaked. In addition to leaks from pipe-linkage, there have been leaks at the filling operations and leaks from the neutralization tank. It is as if "There is a chimney underground," as somebody said. A director of environmental issues at IBM admits that, by pressure testing, it is possible to detect gross leaks from tanks. Originally, however, no one paid attention to the likelihood of leakage. Companies have now to pay the bill for the "saving" of money and superficial "attractiveness".

Factors that affect contaminant transport and the fate of chemicals are 1, volatilization, 2, gravity flow, 3, dispersion in groundwater flow, 4, interaction with soil or sediment, 5, transformation.

1. *Volatilization* means that such chemicals as organic solvents and gasoline may vaporize. The extent of such volatilization will depend on the characteristics of the chemicals, the temperature, the manner of chemical release.
2. *Gravity flow* means that liquid contaminants move downward under the influence of gravity. The contaminants can "sink" or "float" depending on whether or not they are more dense than water.
3. *Dispersion* means that contaminants dissolved in groundwater are transported by the groundwater flow. The organic solvent may condense, for example, 2000 times.
4. *Interaction* with soil or sediment means that contaminants move with the groundwater due to their interaction with the aquifer sediments. The degree to which specific chemicals interact with the aquifer solids depends on the characteristics of both the chemicals and the aquifer solids.
5. *Transformation* means that some contaminants may be transformed by biological or chemical reaction, yielding either harmless or more or less harmful products. In the latter case, for example, 1, 1, 1-trichloroethane is transformed into 1, 1-dichloroethylene (*Ground Water and Drinking Water in the Santa Clara Valley, A White Paper*, 1984, p. A-4).

According to a report produced by the SIA (Semiconductor Industry Association, 1985), while excluding the dilute waste acid stream, the semiconductor industry generates 55 million pounds of hazardous waste nationwide; 13 million pounds are generated in the State of California alone. At the same time,

the semiconductor industry generates 29 billion pounds of waste acid nationwide, 32% of which finds its way into deep wells. 85% of 44,000 pounds of gallium arsenide waste produced by the semiconductor industry has been dumped into a landfill. The high-technology industry itself has therefore become a generator of hazardous waste.

Hazard posed by Drum Recycling

It looked like an international conference, since the organizer of the California Department of Health Services was a Japanese-American, the engineer was a Chinese-American, and the citizen participants were black, white, Hispanic-American and Japanese-American.

It was a community meeting held at Kelly Park's Leininger Center, San Jose, on September 3rd, 1987, called to discuss the pollution caused by Lorentz Barrel & Drum. Lorentz Barrel, a San Jose company, is a 40-year-old drum recycling business that collects old drums, washes them out, repaints and sells them.

In many instances, the drums have contained hazardous wastes which have contaminated the soil and groundwater at the site. The company's owner was sentenced to two years in jail and fines and penalties of \$2.04 million for violation of the state hazardous waste laws, but he died before his confinement could take place.

The Lorentz site had been on the California Superfund list of the state's most hazardous waste sites. Soil at the site and shallow groundwater directly beneath the site were contaminated with benzene, 1, 2-dichloroethane, trichloroethylene and vinyl chloride.

Table 2. Contamination Level at the Lorentz Barrel & Drum Site

Primary Contaminant	Highest Level	EPA MCL	State Action Level
Trichloroethylene	2108ppb	5ppb	5ppb
Vinyl Chloride	1100	1	2
1,2-Dichloroethane	270	5	none
1,1-Dichloroethylene	160	7	6
1,1,1-Trichloroethane	220	200	200
PCB	6.4	none	none

Highest Level Detected ; highest concentration of contaminant found in a groundwater sampling on and near the site.

EPA MCL ; Proposed Maximum Contaminant Level set by EPA.

State Action Level ; Drinking water action levels recommended by the California Department of Health Services set unenforceable water quality standards.

Although contamination of the deeper aquifers that supply drinking water to residents has not been detected, the EPA is nevertheless concerned about the

potential of contaminants to affect these aquifers in the future. It will take much time and money to clean up the site. The investigation has already cost between about 5-15 million dollars. At the community meeting, citizens asked various questions about the effect of pollution on the deep well, air pollution and the responsibility of the original owner of the drums. The citizens movement is trying to put pressure on officials,

1. to get rid of all barrels at the Lorentz site ;
2. to determine exactly how far chemicals have spread underground ;
3. to identify and seek reimbursement from the companies which originally sent their waste drums and chemicals to Lorentz's company ;
4. to monitor air pollution at the site and within a one mile radius ;
5. to conduct an immediate health survey of residents and workers.

To effect the environmental cleanup, the local government is trying to release information, gather information from neighbours, answer their questions, and satisfy their requirements. This tradition of "grass-roots democracy" represents a good guide for environmental policies, especially in Japan. I was impressed that the community should hold such a meeting, and that, after heated discussion, the participants confirmed a decision to achieve a "well Well".

After carrying out the emergency treatment of the contaminated surface soil, State Health officials have decided to turn over responsibility for cleaning up the site to the U. S. EPA. There are two key reasons for this decision :

1. the state has failed to hire cleanup contractors who meet the EPA's standards ;
2. the state needs to turn over complicated and expensive cleanup jobs like Lorentz to the federal Superfund hazardous waste program.

In March, 1988, EPA and California Department of Health Services completed removal of 1,000 drums of hazardous materials. EPA plans to clean up contaminated groundwater. The water will be stripped of chemicals and dumped into nearby Coyote Creek, which flows into San Francisco Bay. A list of the potential responsible parties, the companies — including Hewlett & Packard and IBM — which sent their waste drums to Lorentz's company has now been drawn up.

In California, there are 40-50 drum recyclers, many of whom run small-scale family businesses. Six drum recycling businesses in California are on the State Superfund list of California's worst hazardous waste sites, and, in many instances, the owners cannot afford to pay for the cleanup. State environmental

officials estimate that they will need to spend \$10.5 million to \$20.5 million to clean up the six state Superfund sites (*San Jose Mercury News*, March 14, 1988).

Since drum recyclers take over the responsibility of the treatment of chemical waste instead of the chemical manufacturers and semiconductor industries themselves, such an assumption of responsibility by contractors should be defined as a "shuffling off" of the duty of waste disposal by the industries concerned.

2.3. The Danger of Silicon Valley

Toxic Gas Release

Ambulances and fire fighters are often called out not only to deal with traffic accidents but also to extinguish vehicular fires and container explosions. In Silicon Valley, especially, we can observe the transport of toxic gas on public routes. The semiconductor industries bring in their gases from outside. In California, during the period from January, 1984, through December, 1987, a total of 212 hazardous material shipment incidents were reported, and 258 persons were directly exposed to the involved commodity — mainly corrosive and liquid materials.

According to a study by Cal/OSHA (State of California, Division of Occupational Safety and Health), in 1979, 42 semiconductor companies in Silicon Valley used 570,000 gallons of solvent, 1.56 million gallons of acid, and 1.55 million cubic feet of gas. A city by city report, *Toxic Release Inventory Form*, for 1992 says that a total of 8.5 million pounds of toxic chemicals have been released within Silicon Valley. This is an extremely high concentration of toxic chemicals. In Silicon Valley, many toxic gas accidents have already taken place. For example, silane (SiH_4), which is most frequently used by the semiconductor industry as a carrier gas, is also potentially explosive. In March, 1988, in New Jersey, a silane gas explosion killed three persons. A mixture of silane and laughing gas (nitrogen oxide) seemed to be the cause of the explosion, while, in Silicon Valley itself, local people near route 101 were evacuated during an investigation into an escape of silane gas made by the same manufacturers.

Faced with such incidents as these, Prof. Kenneth Mackay, a meteorologist at San Jose' State University, has carried out a series of toxic gas release experiments. Using the EPA *Chemical Emergency Preparedness Program* (EPA, 1985) as a guideline, he investigated four toxic gases (arsine, chlorine, diborane, phosphine). Arsinine is a highly poisonous, inflammable gas, which destroys red blood cells. The report found that five companies in the electronics valley 50 miles away stored enough arsine to endanger the health of people within a 1.5 mile radius, if they were to breath the gas for several hours in the event of a major release of arsine into the atmosphere.

The five companies listed in the report are Raytheon in Mountain View,

Advanced Micro Devices in Sunnyvale, Exel in San Jose and Precision Monoliths and Epitaxy, both in Santa Clara. This raised the possibility of a major "catastrophe", the "death of the valley" and "a second Bhopal" in Silicon Valley. Bhopal is a city in India, where, in December, 1984, a pesticide factory belonging to Union Carbide, a U. S. multinational company, exploded and killed more than 2,500 people.

Such fears are not unfounded, since in the USA, between 1974 and 1986, there were 69 cases of fire in semiconductor factories, 28 of which were caused by the ignition of flammable or pyrophoric combustion gases (hydrogen, silane).

After five years of discussion, the nation's first toxic gas model ordinance has finally been passed by each city in Silicon Valley. The new law requires the secondary containment of all toxic gases, neutralization apparatus and monitoring equipment. More than 200 businesses will need to spend \$ 100 million to comply with the law according to the Santa Clara County Manufacturing Group.

1989 Earthquake and High-Tech Industry

During the earthquake of October 17th, 1989, chemicals were spilt on to the floor of two Silicon Valley electronics firms — the FMC Corp. plant in San Jose and the National Semiconductor plant in Santa Clara. Silicon Valley, however, was spared a catastrophic chemical accident. According to Bay Area fire fighters, the avoidance of major accidents was due to the tough hazardous material laws. Moreover, the new toxic gas ordinance requires a seismically activated valve that will shut off the gases in the event of an earthquake.

Air Pollution in Silicon Valley

In Silicon Valley, which lies at a drift point on San Francisco Bay, business starts early; some factories begin work at six a.m. This is to avoid traffic jams. From the foot of the mountain, smog spreads across the highways.

An EPA study reported in May, 1987, that ailments caused by dirty and dusty air kill as many 57 residents of Santa Clara County each year. According to the EPA, the main polluter is the motor vehicle. Other organic gas emitters are degreasers for metal processing, industrial solvent coatings and photoresists used in semiconductors. Air pollution caused by the semiconductor industry, however, is still not being thoroughly investigated. According to a monitoring survey carried out by the Bay Area Air Quality Management District, precursor organic compounds from the semiconductor industry (mainly from solvent sinks, mix stations, and photoresist developers) total 11,000 pounds per day; but this type of monitoring is not yet able to detect the presence of inorganic toxic gas. We need much more information about air pollution caused by the semiconductor industry. *A Survey of the IC Industry and Environmental Protection* (1987)

by four Japanese ministries said: "Untreated trichloroethylene and tetrachloroethylene have been detected in the air near the emission apparatus. More attention should be paid to this issue."

In August, 1990, Bay Area Air Quality Management District released a "Toxic Hot Spots" list of significant air polluters. The new list of 123 facilities around the Bay Area includes several of Silicon Valley's most prominent electronics firms — IBM, Lockheed, and United Technologies, National Semiconductor. The Clean Air Act Amendments of 1990 lists 189 toxic pollutants. Factories must install "maximum achievable control technology" to reduce by 90% the release of these pollutants by the year 2000.

In place of troublesome organic solvents, many semiconductor factories began to use CFC (freon gas) as a cleaning agent. In Silicon Valley, IBM's San Jose plant purchased more than 2.6 million pounds of CFC in 1987 and released nearly 1.5 million pounds of CFC in 1987. That probably makes IBM the biggest high-tech user of CFC in Silicon Valley (*San Jose Mercury News*, July 11, 1988). Yet even a cleaner like the CFCs has a negative effect on the environment; CFCs are now known to be destroying the ozone layer and causing the greenhouse effect. Although IBM claimed that air emissions of CFC-113 had been cut by 25% in 1988, they would still have ranked number one in the state, since their emissions were so much greater than that of any other industrial plant. The company has committed itself to a 1993 deadline to phase out CFC usage altogether. In Chapter 4, I shall analyse CFCs in more detail.

Pollution and Safety Problems Relating to Military Facilities

When I drive along route 101, the artery of Silicon Valley, I can see a big hangar beside San Francisco Bay. This is the Naval Air Station, Moffett Field (Base camp for the P 3 anti-submarine patrol plane). Next to Moffett are located the Lockheed Missiles & Space Company and the Onizuka Air Force Base, one of the top five American military command and control centers. There are therefore military aspects to the Silicon Valley problem.

The USA nuclear weapons industry is currently in a state of crisis, rocked by leakages of radioactive waste, equipment breakdowns, plant shutdowns. Around many facilities, the groundwater is contaminated by toxic and radioactive waste. Contaminants are plutonium, cesium, PCB, chromium and solvent. According to the Department of Energy, it will cost \$66,000-110,000 million to clean up the mess.

Many of the military base camps surrounding San Francisco Bay store nuclear weapons and are also contaminated by chemicals. Among them, Moffett is the worst and is listed as a federal Superfund site. 19 separate sites on the facility have been contaminated with millions of gallons of toxic waste over the

past 40 years. The contaminants include petroleum hydrocarbons, solvent, oils, metals, paints, and battery acid.

In July, 1988, a community meeting was held near Moffett Field. Besides Moffett, Intel and NEC are the main polluters. Some retired couples attended this meeting. Because they were worried about the drinking water, they discussed the safety of boiled water and how to press the officials to take proper preventative action.

Missiles, too, present safety problems. We easily remember the explosion of the Space Shuttle, Challenger. In the USA between 1987 and 1988, there was more than one explosion of a missile fuel facility; in December, 1987 at the fuel factory for MX missiles, in Utah; in May, 1988, at the fuel plant for the Space Shuttle and the Titan missile, Nevada.

United Technologies, Chemical Systems Division, southeast of San Jose, handles the same fuel as the Nevada plant and also manufactures such missiles as the Minuteman, Tomahawk, Trident and Titan. The Air Force inspectors found defects in an average of one of five components for missile motors. The firm was cited for "severe fire threats" and explosives hazards (*San Jose Mercury News*, Nov. 24, 1987). The company's engine tests and open air burning of excess rocket fuel impacts neighbors up to 20 miles away and spews forth almost one million pounds of highly toxic chemicals into the air, including hydrogen chloride and aluminum oxide.

Recently, soil and groundwater contamination has occurred at this site owing to leakage from three hazardous waste ponds where various hazardous waste products were stored. At the same time, organic solvent was seeping through the ground close to Anderson Reservoir which provides drinking water for up to 300,000 people. In August, 1988, and September, 1989, the Altus Corp., San Jose, which manufactures lithium batteries that are sold primarily to the military, belched huge clouds of black, toxic smoke. This plant has been cited by federal and state agencies for 15 violations during the past 5 years. This dangerous factory is located in the center of San Jose City.

2.4. Occupational Safety Problems

Health Hazards to Semiconductor Industry Workers

Debbie Berry suffered severe headaches and difficulty in breathing. Between 1985 and 1986, she worked for a semiconductor company, Siliconix Santa Clara, engaged in cleaning with cellosolve (Ethylene glycol monoethyl ether). Because she suffered from a stroke and trembling hands, she was fired. She claims that her work would have been safer had there been a correct ventilation system and alternative chemicals. About 200 persons are suing the company: "We are guinea pigs".

After working for several years for a semiconductor company, Signetics, Gene Lemon, a chemical engineer, developed a disease of the respiratory organs as a result of exposure to chemicals; he sued the company. In Silicon Valley, therefore, semiconductor workers and engineers face many health hazards. During the 1970's, nausea and headaches suffered by semiconductor workers in Silicon Valley attracted attention.

Dr. Joseph LaDou, the author of "The not-so-clean business of making chips" (*Technology Review*, May/June 1984), has tackled this type of problem. He is Clinical Professor of Occupational & Environmental Medicine, University of California, San Francisco, and also works at the Peninsula Industrial Medical Clinic, Sunnyvale. According to Dr. LaDou, about 50% of the injuries and illnesses suffered by workers in the semiconductor industry are not reported to the federal survey.

Furthermore, until 1981, accidents caused by exposure to toxic gasses had been reported as "illness"; after 1981, however, they were reported as "injuries". Gas exposure cases are therefore only reported in serious cases.

On the other hand, the California Workers' Compensation Statistics has collected more detailed data about the semiconductor industry in California. Statistics for "Occupational illness as percent of workloss cases", "Systemic poisoning as percent of occupational illness", "Systemic poisoning as percent of workloss cases", reveal that the number of such cases in the semiconductor industry is relatively high, seven times higher than in any other branch of manufacturing.

Table 3. Occupational Illnesses in the Semiconductor Industry
(California Workers' Compensation Statistics)

	1986	1987	1988	1989	1990	1991
<i>Occupational Illness as Percent of Workloss Cases</i>						
All Manufacture	7.0	7.0	7.5	6.9	8.4	9.1
Electronic Component	16.9	18.7	17.3	14.4	19.9	16.5
Semiconductor	21.1	26.4	22.4	16.5	21.1	18.4
<i>Systemic Poisoning as Percent of Occupational Illness</i>						
All Manufacture	20.6	17.4	17.0	16.6	15.6	13.9
Electronic Component	39.7	31.4	30.7	35.6	28.5	28.7
Semiconductor	49.6	34.3	39.8	40.8	37.9	25.6
<i>Systemic Poisoning as Percent of Workloss Cases</i>						
All Manufacture	1.5	1.2	1.3	1.1	1.3	1.3
Electronic Component	6.7	5.9	5.3	5.1	5.7	4.7
Semiconductor	10.5	9.1	8.9	6.7	8.0	4.7

Even the Bureau of Labor Statistics (1984, 1985) admitted that the percentage of illness attributed to "respiratory conditions due to toxic agents" and "skin diseases or disorders" was higher for the semiconductor industry than for manufacturing overall. This relatively high rate of systemic poisoning in the

semiconductor industry is noteworthy.

There are several sources of potential danger: 1, many sorts of chemicals and gases; 2, non-ionized radiation (laser, ultraviolet); 3, ionized radiation (α , β , x ray). There are various sorts of health hazard here: 1, carcinogenic (arsine, benzene, trichloroethylene etc.); 2, reproductive (cellosolves, lead, etc.); 3, immunological (so-called "chemical AIDS"). Workers fall sick after acute exposure, or long-term, low density exposure. Dr. LaLou states that because high-speed microelectronic devices often require wafers composed of arsenic and gallium, these poisons are being used in ever-larger quantities. As a result, the production of gallium arsenide wafers requires much greater care if the workers are not to be endangered by the toxic arsenic powder. At the same time, safer materials should be and now are being developed, however, and the old materials are being replaced.

As *Semiconductor Industry Study* (1981) published by Cal/OSHA stresses, "unusual" work such as maintenance can also cause trouble. In Japan, from 1966-1985, there were 22 cases of toxic gas exposure during this sort of work in the semiconductor industry. However, *A Survey of the IC Industry and Environmental Protection* (1987) by four Japanese ministries said, "No information is available about the work of changing gas cylinders, pump oil, or maintenance work such as piping." Further study needs to be undertaken and improvements should be carried out.

Nor should the safety problems of minority workers at high-technology related companies be ignored. For example, female minority workers often use organic solvents at "garage" size work places which manufacture printed circuit boards. As the cost of living — especially housing — has climbed rapidly in recent years, so the proportion of Asians living in Silicon Valley has risen, too, as they seem more willing to share tiny living spaces. At the circuit-board manufacturer Flextronics, where unskilled jobs are plentiful, roughly 50% of the work force have Asian backgrounds, while 20% are Hispanic (*San Francisco Chronicle*, July 18, 1988).

Early in the morning, many people stand in line at the federal emigration office in San Jose. Silicon Valley, a center for high-technology is, in fact, also a center for refugees from Vietnam. About 100,000 Vietnamese live in San Jose. Light railroad notices are written in English, Spanish and Vietnamese. Some of the Vietnamese work in the electronics industry. But the real state of things is not clear.

At the same time, as more multinational companies of the semiconductor industry are being located in southeast Asia, the occupational exposure of workers has begun there too. For example, in January, 1983, at an electronics factory making DC motors in Hong Kong, owned by Mabuchi Motors of Japan,

193 women workers were sent to hospital after breathing high levels of ozone, phosgene and other gases which had been slowly released by printing equipment which used ultraviolet light. 13 of the victims were pregnant at the time of the incident. According to some of the Mabuchi workers, at least 6 of those women experienced miscarriages or underwent forced abortions because of fetal death.

By 1992, Malaysia had become the largest semiconductor exporting county in the world. Vivian Lin carried out research of the working conditions of five semiconductor facilities (assembly line) in Malaysia and Singapore, where night work by women is allowed. Her survey shows that workers using solvents regularly are more likely to experience problems with menstruation, pregnancy and childbirth.

Spontaneous Abortion among Semiconductor Workers

In January, 1987, AT & T, a famous telecommunication company and also a big semiconductor manufacturer, banned pregnant women from production lines because of concern about the employees' exposure to chemicals that might cause miscarriages. AT & T implemented this policy after learning about a health study in Massachusetts that reported an increased rate of miscarriages among chip production workers.

The Division of Public Health, University of Massachusetts, carried out this health study of employees (744) at DEC, Hudson LSI. Personal interviews were conducted with manufacturing workers, the spouses of male workers, and an internal comparison group of non-manufacturing workers. Elevated spontaneous abortion ratios were observed for females working in the "diffusion" (38.9%) and "photolithographic" (31.1%) processes.

Various general symptoms of sickness such as arthritis, nausea, rashes, sore throat, headache were examined and reported more frequently among those workers in the manufacturing process than among the non-exposed.

Since about 66% (1984) of the workers in the semiconductor industry are women, this study has revealed a serious problem. Critics have attacked the method of this study, and the federal OSHA admits that it needs to be followed up by much more investigation. AT & T, IBM, DEC, SIA have carried out more research. Based on the IBM and SIA studies, they will phase out glycol ether (EGE) of their plants. DEC and AMD allow a pregnant woman the option of transferring to another job. The response of the Santa Clara Center for Occupational Safety and Health, an organization seeking workers' safety, is "Remove chemicals, not workers". They claim that AT & T has adapted a discriminatory policy of excluding pregnant women from certain production areas, without considering the effect of toxic chemicals on the reproductive systems not only of women but of men as well prior to conception. Policies singling out pregnant or

fertile women for removal may violate Title 7th of the 1964 Civil Rights Act which forbids employment discrimination on the basis of sex or pregnancy. As a result of exclusive policies, women have lost employment possibilities. Some companies are entitled to protect themselves against the possibility of lawsuits brought by the injured offspring of employees. Workers argue that companies should; 1, replace substances known or suspected of causing harm with safer substitutes; 2, institute engineering controls such as enclosure or ventilation; 3, transfer workers temporarily without loss of wages, seniority or benefits, while efforts proceed to reduce the hazard; 4, finance independent industrywide studies to assess the health effects of workplace exposures; 5, integrate the concept of occupational and environmental health and safety into process design; 6, provide independent training and positions for workers, health and safety representatives.

California state used to require its own OSHA (Division of Occupational Safety and Health) to inspect and regulate over a wider range than does the federal OSHA. In 1987, however, Governor George Deukmejian abolished the Cal/OSHA for financial reasons, notwithstanding that the annual cost of Cal/OSHA was really only \$6.8 million — \$8.4 million, less \$1.6 million in loss and penalties. Such expenses are not great when we consider that the overall size of the state budget is \$42 billion. There had been wide private criticism among businesses, however. The reason is simple: California employers are already burdened by one of the most expensive compensation systems for job-related illnesses and injuries (*San Jose Mercury News*, Oct. 22, 1987). After the abolishing of the Cal/OSHA, inspections dramatically decreased, and workers deaths increased by about 50%. Therefore, in November, 1988, a state ballot voted to restore Cal/OSHA.

This chapter has demonstrated that Silicon Valley not only suffers from groundwater contamination by organic solvents, but also faces many other problems that affect the environment, general safety and occupational health.

3. Tackling the Cleanup

3.1. The Environmental Protection Movement in the USA

Citizens' Cleanup

Although Ted Smith is an attorney, he no longer stands at the bar. He is engaged instead as the Executive Director of Silicon Valley Toxics Coalition. Originally, as a lawyer who specialized in labour problems, with his wife, Amanda Hawes, who specialized in workers' safety, he tackled the "Fairchild case". This coalition is composed of many sorts of citizen, environmental groups ("Citizens for Better Environment"), occupational safety groups and labour unions (AFL-CIO). Because unions are not permitted to organize workers at high-tech industries, they make much of occupational safety and environmental problems.

Consequently, the high-tech industries themselves regard "Coalition" as a separate arm of the unions.

The American environmental protection movement has two mainstreams: one is the wildlife protection movement like the Sierra Club; the other is the anti-toxic waste movement. The Silicon Valley Toxics Coalition, however, has a good relation with other wildlife protection movements, while the environmental movement is building up a closer connection with the labour movement as a result of tackling nuclear waste and toxic waste problems.

The first project undertaken by the Silicon Valley Toxics Coalition has been to fight for local legislation to require safer containment and monitoring of chemical storage, and to require public disclosure of toxic chemicals stored in the communities: 1, to persuade the EPA to declare the Santa Clara Valley sites Superfund sites; 2, to ask the state to carry out a study of birth defects in the Fairchild spill area; 3, to ask the County Board of Supervisors to establish a Safe Water Council to move on solutions to toxic waste problems; 4, to push the Legislature to appropriate more funds for toxic hazard identification and clean-up; 5, to ensure safer toxic chemical storage practices; 6, to encourage government and industry to move faster on cleanup efforts.

Hereafter, I would like to analyse how far these objects have been achieved.

Proposition 65

It is noteworthy that California voters overwhelmingly (68%) adopted Proposition 65, the Safe Drinking Water and Toxic Enforcement Act of November, 1986. Governmental agencies will no longer consider the use of chemicals known to cause cancer or reproductive toxicity "innocent" until proven "guilty" of harming public health. After February, 1988, anyone who in the course of business exposes any individual to a chemical "known to the state to cause cancer or reproductive toxicity" must first provide "clear and reasonable" warning of the exposure. This new regulatory process creates incentives for businesses to cooperate with governmental agencies in establishing levels that define "no significant risk" and to reduce their use of toxic chemicals.

Most of the high-tech industries naturally opposed Proposition 65, and gathered \$ 0.6 million to organize an anti-proposition campaign. On the other hand, Hollywood actors and actresses supported the citizens' campaign for Proposition 65.

In Californian restaurants you are asked to observe that there are "smoking or non-smoking" area for diners. Official warnings about smoking are already familiar to the Japanese. Similar warnings about chemicals which could cause birth defects or other kinds of reproductive harm are printed on labels or are available on free-phone. The focus of the problem is how to decide what consti-

tutes "significant risk". For example, the carcinogenic potential of alcohol, charcoal-cooked steak and furniture polish, etc., has also been considered.

In February, 1987, the Governor of California named a scientific advisory panel of 12 scientists to advise him about which chemicals should be included on the Proposition 65 list of carcinogens and reproductive toxicants. As of 1990, the list has grown to include about 350 compounds.

We have to take note that Proposition 65's powers to prevent environmental pollution are limited by its *inability* to control the substantial risks associated with high background levels of carcinogenic exposure. At the same time, "no significant risk" ignores the potential magnitude of cumulative cancer risks from *multiple* exposures to *different chemicals*. In establishing its "significant risk" standards—one additional case of cancer per population of 100,000 (which means 280 persons in California State)—the administration split the difference between the business and environmentalist positions. Environmental groups had asked that one additional cancer per 1 million people be the standard of unacceptability, while businesses asked that it be one per 10,000.

Although businesses and the governor fear that Proposition 65 could frighten people unnecessarily and have a negative economic effect, we have to remember that the background of Proposition 65 is that people already genuinely fear environmental pollution.

According to a telephone survey of 1,000 Santa Clara County residents (June, 1988) about water quality, 68% people believed that it was a "big problem", while 54% thought that "there are probably some unsafe things in the water that you cannot see." In fact, because about half of the Santa Clara County residents no longer drink tap water, bottled mineral water sells very well.

As Proposition 128 of 1990, known as "Big Green", which was trying to phase out 20 cancer-causing pesticides, to ban CFC, to protect the coast, to reduce by 20% emissions of global warming gases and to protect old redwoods, was not passed, Proposition 65 grows ever more significant.

3.2. Conduct of Government

EPA (US Environmental Protection Agency)

"Political Football" is a term coined by Lenny Siegel, a coauthor of *The High Cost of High Tech* (New York, Harper & Row, 1985), about the response of government to pollution in Silicon Valley. As he pointed out, high-tech pollution is kicked about between federal, state, county, city and district.

EPA, the agency responsible for the whole program and money procurement, has made much of the pollution of Santa Clara County, and has proposed to establish an "Integrated Environmental Management Project" (one of four nationwide projects) for this area.

This project's goals are 1, To evaluate and compare the health risks from toxic pollutants in the environment ; 2, To use these pollutants in the evaluation to set informed priorities for further analysis and possible control ; 3, To work closely with government agencies and the community to manage environmental public health problems effectively.

In October, 1984, EPA listed 19 Superfund sites in this area. Since then, the number of Superfund sites has grown to about 33, 10 of which have been transferred to another program. Superfund was to be funded from taxes on crude oil and 42 different commercial chemicals. State governments were to pay 10 percent of the cost of Superfund work at privately owned sites and 50 percent at those which were publicly owned. Superfund was to be used in cases where responsible parties could not be held accountable or were unable to respond to emergency situations involving hazardous substances. There would be some cases of "mixed funding" between the fund and responsible parties to share remedial costs. In Santa Clara County, however, businesses don't always support the Superfund list.

DOHS (California Department of Health Services)

The California Department of Health Services judges the water quality, manages large-scale wells and is responsible for the application of State Superfund. This department has carried out epidemiological studies of Los Poseos. The action level for the state, that is the regulation level of water insisted on by California State, is more strict than that of WHO (World Health Organization) and Japan. The regulation levels set by WHO and Japan are tetrachloroethylene 10 ppb, trichloroethylene 30 ppb, 1, 1, 1-trichloroethane 300 ppb. The comparable action levels of California State are 4 ppb, 5 ppb, 200 ppb. Susanne Wilson, chair of the safe water council of Santa Clara County, has nonetheless criticized the policy of the state. She recommended that the regional water board promptly receive an augmentation of 22 staff members. The State Department of Health Services has rejected this request. As long as the contamination remains below state action levels, the state has defined all possibilities of additional state purification as irrelevant. Ms. Wilson's great concern is that individual firms or state agencies may view the application of State and Federal water quality standards as a license to pollute. She added that the delay in making use of Superfund is the fault of the state. In 1985, when the State Assembly proposed a \$8.5 million cleanup program, the Governor rejected it. In 1991, a part of DOHS was reorganised into Cal/EPA.

RWQCB (Regional Water Quality Control Board)

The California Regional Water Quality Control Board, San Francisco Bay

Table 4. Hazardous Materials Program in California

<i>Hazardous Materials Control</i>
1. State Regulation of Underground Storage Tanks (Sher Bill)
2. Hazardous Materials Storage & Emergency Response (Waters Bill)
3. Acutely Hazardous Materials Risk Management (La Follette Bill)
4. Emergency Planning and Community Right-to-Know (SARA Title III)
5. Uniform Fire Code (1988 Edition)
6. Worker Right-to-Know (Fed OSHA, Cal/OSHA, Occupational Carcinogens Control Act)
<i>Hazardous Waste Regulation</i>
1. Hazardous Waste Management Planning and Facility Siting (Tanner Bill)
2. Federal Regulation of Hazardous Wastes (RCRA, HSWA)
3. Federal Toxic Cleanup Law (CERCLA, SARA)
4. State Superfund, Hazardous Substances Account Act
5. Toxic Pits Cleanup Act (Katz Bill)
6. State Regulation of Hazardous Solid Waste Disposal (Calderon Bill, Eastin Bill)
7. State Hazardous Waste Control Law (HWCL)
8. Hazardous Waste Management Hierarchy
9. Incentives and Assistance to Improve Hazardous Waste Management
10. Household Hazardous Waste (HHW) Management
<i>Other Toxics Laws and Programs</i>
1. Proposition 65 (Safe Drinking Water & Toxic Enforcement Act 1986)
2. Asbestos (OSHA, EPA) (DHS, Cal/OSHA)
3. Safe Drinking Water (Federal SDWA, California SDWA)
4. Industrial Waste Pretreatment Programs, (Controls Toxic Discharge into Sewers)
5. Clean Air Act (Federal CAA, Cal CAA, "Toxic Hot Spots" Bill)
6. Water Quality Control (Federal Clean Water Act, Porter-Cologne Water Quality Control Act)
7. Pesticides (FIFRA, Cal Pesticide Contamination Prevention Act, Restricted Materials Act)
8. Transportation of Hazardous Materials and Wastes (Fed Haz Mat Trans Act; RCRA, Cal Vehicle Codes & C 8)
(Source; <i>EPICS International</i> , 1990)

Region, has about 100 members of staff, and is responsible for managing and investigating the water quality and directing each company. The State of California has nine Regional Control Boards, all of which are short of staff. The local government has direct responsibility, but little resources or means.

SCCPHD (Santa Clara County Public Health Division)

The County Authority is a branch of local government between the state and the cities, responsible for fire, public health, welfare and safety. Santa

Clara County Public Health Division controls the small-scale wells and regulates the underground storage tanks. This Division has about 10 toxics specialists, who must investigate the possible contamination of about 1,200 private-wells. Although, in 1985, a special committee, composed of members from each branch of local government, was set up, the real responsibility for pollution control is not clear. Santa Clara County has about 24 federal and state pollution control laws (see Table-4), but each law is very complicated and some are duplicated.

SCVWD (Santa Clara Valley Water District)

Before Santa Clara County became a concentrated high-tech area, it had many orchards, and, about 70 years ago, this Water District was authorized to control agricultural water and flooding. Today, the District gathers the ground-water tax and collects data of the groundwater quality; it is also responsible for closing contaminated wells.

In January, 1982, after the Fairchild case, the Santa Clara Fire Chiefs Association proposed a Hazardous Materials Model Code which would provide double containment and strict monitoring of all toxic chemicals. In 1983, the County and each city implemented Model Ordinances based on this proposition. Later, state laws were passed to regulate toxic chemicals. Virtually all the 4,000 facilities that have submitted Hazardous Materials Management Plans have been inspected. About 500 double containment tanks have been constructed, 1,400 tanks have been transferred, and 322 tank leakages have been reported. The ordinance has therefore taken effect, to some extent, specifying and examining hazardous materials storage sites.

City

Each city has implemented a hazardous materials storage ordinance to regulate underground storage tanks and to control toxic chemicals. As for "trade secrets" relating to the chemicals used by the industries, for example, San Jose City Hazardous Materials Storage Permit Ordinance, "Trade Secret", stipulated that, "The exact name of the trade secret material,—be placed in a double-keyed lockbox and maintained in at least two locations at the facility,— key shall be — accessible to permittee's designated emergency response person." I have heard that at the time of implementation discussions focused on secret policies against terrorists and rival Japanese companies. Today, San Jose City is providing guidelines for user financing, information advice and treatment of household toxic waste.

Integrated Environmental Management Project

The purpose of the Integrated Environmental Management Project is, as I

have said, to identify and define risk to public health posed by exposure to toxic contaminants such as polluted groundwater, and air trihalomethanes (THMs) etc., to assess the relative risks of exposure to such dangers, and to control the likelihood of such risks more efficiently.

The Draft Stage One Report released in October, 1985, focused on 30 contaminants, polluted air and the carcinogenic potential of polluted drinking water. On the one hand, this report stressed the risks of air pollution and the presence of trihalomethanes in surface water. On the other hand, it estimated only low risk from contaminated groundwater. The Silicon Valley Toxics Coalition criticized the report since it concentrated only on 30 substances and excluded the risks from stored chemicals during fires or earthquakes. The risk assessments tend to be manipulated.

The Stage Two Report appeared in September, 1987; it had carried out a cost-benefit analysis of the cleanup of groundwater and surface water. The report stated that "widespread treatment (of groundwater) may be more costly than obtaining replacement supplies. Also, closure (of well) is projected to entail a greater risk than treatment, since users of closed wells are assumed to be provided with surface water replacement supplies (which present a risk of cancer from THMs)" (pp. 3-69~3-73).

After discussion between government, business and citizens, an action plan for this project agreed over the air, water and institutional issues. Since I listened to the discussion, I would like to mention some of the controversial issues raised. The business side asserted that their efforts for cleanup should be evaluated favorably, but that the technological problems were large and complicated. Although the business side hoped that clean air regulations applied to special industries would not be necessary, the "action plan" agreed on the need to "improve its data base on emissions from industries, including semiconductor and high-tech facilities" (item 5).

Although the labour side asked for the outright banning of cellosolve (glycol ethers), it was decided that "further research leading to phasing out the use of toxic glycol ethers should be performed" (item 6).

Water issues were dealt with accordingly: 1, as to the hazardous materials ordinance, "Coordinate inspection activities to minimize duplication", and "Explore the possibility of centralizing data collection"; 2, as to private wells, "complete the private wells testing program", and "implement the following testing"; 3, as to aquifer management, contrary to the opinion of business, "Where restoration of the aquifer is too costly, responsible parties fund measures that mitigate or compensate for the residual impacts of their contamination" (item 14), while "Protection zones should be developed" (item 17). On the other hand, a "Waste Reduction" scheme, proposed by the Silicon Valley Toxics Coalition,

was not included at this stage.

The action plan evaluated the status quo over institutional issues; "there is no formalized, well-defined process for toxics management decision-making." The action plan therefore proposed the establishment of a "Santa Clara County Toxics Policy Council." This Council was to be characterized as a joint powers authority and be based on multiparty agreement.

Although this Council has not been set up, the "Tanner Advisory Committee" attached to the County Supervisor is now working to improve the management of toxics and solid waste.

It is noteworthy that in order to decide upon an environmental policy, the government proposed a draft plan openly and organizes discussion and full negotiation. Japanese environmental policymaking should follow this example.

3.3. Tackling Cleanup by Businesses

Fairchild

When I visited the Fairchild Company, San Jose, only the aeration machine was at work. Well #13, 2000 feet away, had been closed down in 1982. After discovery of the pollution, Fairchild removed 3,389 cubic yards of contaminated soil, extracted and treated groundwater to reduce the level of chemical concentration (TCA level is 24 ppb, January, 1990). Fairchild also installed an underground slurry wall which is three feet wide and runs vertically to depths from 80 to 140 feet beneath the plant site. According to the EPA, however, the slurry wall is not the final remedy and the citizens point out that slurry walls have a tendency to leak. In September, 1987, the National Semiconductor Company bought out the Fairchild Company. Fairchild, however, retained all environmental liabilities associated with its past activities at the site. The San Jose Fairchild site is to become a shopping center.

IBM

IBM is the largest captive semiconductor manufacturer in the world. IBM, San Jose, has 14,200 employees, the third biggest company (the first is Lockheed missile & space, the second, Hewlett & Packard) in Silicon Valley. The IBM plant is located about 1.5 miles northwest of the Fairchild site. Some IBM employees live near by. Since few Fairchild employees live in Los Poseos, local hatred of Fairchild has been very strong. On the other hand, IBM has a "company town", where a citizens movement is difficult to organize. In fact, an IBM employee was originally involved in the Fairchild case, but later dropped out.

Contamination from the IBM plant has already affected about 25 public and private wells. More than 100,000 San Jose residents are potentially exposed to contaminants in these wells. IBM has already spent \$200 million in cleanup and

dug more than 300 monitoring wells and 19 pumping-up wells. Nonetheless, the Silicon Valley Toxics Coalition criticized the methods of this cleanup.

1. It is necessary to dig more monitoring wells and grasp the extent of the pollution more exactly. Since RWQCB ordered IBM in 1984 to clean up only the "first area", there is the possibility of pollution in the lower northern area.
2. IBM is pumping up to 12 million gallons of contaminated groundwater into Canoas Creek everyday. But this water could easily pollute other groundwater.
3. The aeration used for cleanup may cause air pollution.

Because of the Californian water shortage, IBM reused 68% of the water it pumped in August, 1990, for irrigation or for on site manufacturing purposes. IBM has a toxics division and a stricter environmental standard than the federal government. It will be interesting to see how IBM tackles further cleanup in San Jose.

Clean Water Task Force

The cost of cleanup is higher than the land price itself. For example, in the case of Fairchild, the land price was \$5 million, while the cleanup cost \$30 million.

The Comprehensive Environmental Response Compensation, and Liability Act of 1980 (CERCLA), known as "Superfund", defines four categories of persons who are financially responsible for hazardous waste cleanup: Past owners, Present owners, Transporters of hazardous substances, Generators of hazardous substances. As a result, current property owners who have not caused contamination may still be financially liable for any contamination associated with their land. This concept may extend to financial institutions. The Superfund Amendments and Reauthorization Act of 1986 (SARA) amended CERCLA and created an "innocent purchaser" defense to owner responsibility. To claim innocence, however, the landowner must first demonstrate that at the time of property acquisition there was "no reason to know" that the property was contaminated. Since investigation of pollution is therefore necessary, the expert is naturally eagerly sought after.

The Clean Water Task Force was consequently formed in 1984 to encourage and support activities by member industries in Santa Clara Valley to protect and conserve drinking water. It is an organization sponsored by the Santa Clara County Manufacturing Group. Its environmental Programs' Director, Jacqueline Bogard, is another "iron lady", confronted by environmentalists. According to a

survey of 74 companies responding, since 1982, 254 extraction wells have been installed and 15 million gallons per day have been extracted. The water reuse rate is only 1.11%. A total of 2,006 monitoring wells are actively being sampled. More than \$65 million has already been spent on investigative studies at these sites. The number of secondary containment tank systems rose from 211 tanks in 1982 to 372 tanks in 1987. The companies surveyed have spent more than \$28 million since 1982 on preventative measures. Since the RWQCB requires industry to sample many monitoring wells and as it takes much time and money, industry has expended enormous resources on investigative work.

According to Jacqueline Bogard, EPA's Superfund is not necessary, because in Silicon Valley industries themselves have already taken action to cleanup. In the case of Superfund, the EPA requires much documentation and the federal fund cannot be used except in case of bankruptcy. How is it possible for society to use limited resources to reduce the pollution to zero, she asked about the "How clean is clean" problem. The standards should be decided by science itself, and should not be affected by politics. She complained, however, of the companies' responses, because the companies contradicted each other over responsibility for the pollution and they tended not to disclose vital information.

On the other hand, citizens are not happy with Ms. Bogard's opinions about an "acceptable risk". Health standards themselves have to be based on health data alone, not cost. One part per billion of 1, 1, 1-trichloroethane in a liter of water is the equivalent of a million molecules. And after all, during the first trimester of pregnancy, a woman undergoes enormously rapid cell division when the infant's heart is forming; those molecules may spread equally rapidly.

Jail Sentences of Environmental Violators

Prosecutors are getting tougher on environmental violators. Recently, two corporate officers in Silicon Valley, Universal Semiconductor and Golden State Circuit, faced criminal liability under environmental laws. From the start, the Clean Water Act and the Resource Conservation and Recovery Act (RCRA) contained versions of the "knowing endangerment" rule, which provides for penalties of fine or imprisonment (or both). Since the federal sentencing guidelines of November, 1987, were instituted, however, the number of criminal prosecutions has increased. In Silicon Valley, the district attorney's environmental crimes unit investigated about 100 violations of local and state hazardous waste laws a year. In 1990, complaints have resulted in 5 jail sentences and about 60 fines.

Water Shortage

Yosemite is a famous National Park. Hetch Hetchy Reservoir in Yosemite

supplies 20% of the water used in Silicon Valley. While Hetch Hetchy water contains only about 30 milligrams per liter of particles, Santa Clara's two underground wells contain 300 to 500 milligrams of particles per liter. It is much more difficult and expensive for business to purify well water.

Over the past 5 years, pumping for cleanup has caused the groundwater level in the area to drop by nearly 30 feet. Faced with such a drastic decline in their groundwater supply, the RWQCB gave IBM and Fairchild permission to leave more contaminated water in the ground. That angered both environmentalists and Betty Roeder, who owns the Great Oaks Water Company. She has refused to supply her customers with water that contained any detectable levels of industrial chemicals. Despite the board's arguments, even Fairchild representatives said they are reluctant to slow the pumping. They fear Fairchild could face lawsuits (*San Jose Mercury News*, Feb. 6, 1988). Since high-tech industries use so much high quality water, they have to face a water shortage and the skyrocketing of costs for water. In March, 1990, IBM built a sophisticated water treatment plant to pump water from a contaminated aquifer, use it and then re-inject clean water back into the ground.

3.4. What can we learn from Silicon Valley ?

"Waste Reduction"

I would first like to mention two recent developments in tackling the cleanup, and then attempt to sum up what we can learn from Silicon Valley.

1. *The enforcement to tackle "waste reduction".*

Because of the strict federal regulations on waste landfill levels, industries have to locate new disposal sites or introduce new treatment methods. In Santa Clara County, about 100,000 tons of hazardous waste are generated a year. If this waste were reduced at the site, the number of storage tanks and the possibility of corresponding leakage from tanks would decrease. The county is now preparing to encourage "waste reduction".

2. *EPA's Technical Assistance Grant Program.*

Recognizing the need for citizens to be well informed of the conditions and activities at Superfund sites in their community and the importance of informed comment from citizens, Congress established the Technical Assistance Grant Program as a part of the Superfund program. The Technical Assistance Grant Program provides grants to citizens' groups to obtain assistance in interpreting information related to the cleanup at Superfund sites. In February, 1989, EPA awarded Silicon Valley Toxics Coalition a Technical Grant amounting to \$50,000, one of the first in the nation. The Coalition then proceeded to hire two consultants, who commenced work to evaluate

the IBM site. In April, 1993, the \$100,000 award was granted. The grant will allow the Coalition to hire a technical advisor to assist it in participating in the management of the investigation and cleanup activities at the Moffet Field Naval Air Station Superfund site and the adjoining Middlefield-Ellis-Whisman Superfund site in Mountain view.

Lessons from Silicon Valley

We have to learn many lessons from Silicon Valley.

First. Pollution is vast and very serious. The cost of the cleanup is enormous. Total recovery is impossible. Groundwater pollution by storage tanks is especially dangerous. In the case of Japan, although groundwater contamination is already confirmed, thorough investigation has been delayed. It is absolutely necessary to examine not only the exhausted gas holes and drainage systems, but also underground storage tanks and surrounding wells.

Second. Since high-tech pollution is, by nature, a complex chemical reaction, the focus must be on the management of chemical substances. It is desirable for industries to disclose information about the materials which they use. We have to pay attention to the fact that in Silicon Valley people came rightly to suspect the harmfulness of 1, 1, 1-trichloroethane, which in Japan is regarded as comparatively safe.

Third. The concentration of high-tech industries poses potential hazards to local residents, since the storage of many sorts of chemical and gas is highly concentrated, and must be transported into and out of the industrial site. Safeguards against fire, earthquake and accident are therefore indispensable. Even in the case of a planned location for a facility different from Silicon Valley, such safeguards are necessary.

Fourth. It is very important for governments to disclose their information and allow citizens to organize, clean up and control pollution. In Silicon Valley, the citizens' involvement has stimulated all levels of government to take action in a relatively short time. And although it is true that not all the problems have been solved, citizens' involvement indicates a good model for Japanese environmental policy. In Japan, environmental surveys released by government departments generally include no names of specific factories, while hearings from residents are often perfunctory.

Last. I would like to propose that there is a relationship between the environmental problem and the trade friction problem. I have often heard that since Japanese companies steal technical information, American companies cannot disclose the name of chemicals in the factories, or that competition with Japan hampers investment in safety. Japan is made an excuse for oppressing American citizens. It is high time that the citizens of both countries exchanged informa-

tion, especially concerning safety and problems of health.

4. The Real Semiconductor Industry

4.1. The Characteristics of the Semiconductor Industry

What is a semiconductor ?

I would here like to offer a brief description of an IC (Integrated Circuit) and a LSI (Large Scale Integrated Circuit), the pivots of the high-tech industry. The parts consist of three categories: the first is a conductor which carries electricity; the second is an insulator which does not carry electricity; the third is a semiconductor which will carry electricity if the conditions are appropriate. A semiconductor carries electricity when it receives light or heat; this means that a semiconductor changes its character from "not carrying electricity" to "carrying electricity" depending on conditions. The convenient character of a semiconductor enables it to memorize letters and numbers and to compute quickly. A semiconductor computes by the binary scale of only 1 and 0. 1 represents the "on" of electricity and 0 represents the "off" of electricity. A semiconductor switches very fast from one to another, 10-20 million times per second.

A semiconductor does not memorize letters and figures as they are, but memorizes by cutting them at right angles, each black part and white part corresponding to an electrical "on" and "off". When a special sort of semiconductor receives electricity, it activates the movements of an inner electron and emits lights at a high level of energy. This is a LED (a Light Emitting Diode). There are many sorts of semiconductor which synthesize sounds or respond to lights and so on.

"A Visit" to a Semiconductor Plant

I would like to invite you to "visit" a semiconductor plant. The semiconductor manufacturing process consists of two main steps: the first is "wafer" manufacturing; the second is "assembly" and "inspection". The wafer is fabricated by introducing impurities (dopants) to purified silicon, which may sound a paradox.

First of all, a silicon or gallium arsenide ingot is "grown" by chemical process (Crystal Growing). The semiconductor ingot is shaped and sliced into thin wafers (Ingot Grinding and Sawing). The wafers are treated with chemicals to give them a very clean and smooth surface (Wafer Preparation). A thin, non-conductive layer of silicon dioxide is "grown" on the wafer (Epitaxy and Oxidation). The desired pattern for the electrical circuit is etched into the wafer with a set of photomasks and ultraviolet light (Photomasking and Etching). The exposed patterns are doped at high temperatures to result in electrical circuits in each "chip" on the wafer (Diffusion). These processes are repeated.

To avoid the settling of dust, which would degrade a semiconductor, cleanliness is essential during all parts of the manufacturing process. Operatives, for example, are not allowed to wear makeup, and one Japanese semiconductor manufacturer, who merged with a Silicon Valley company, directed his workers, who came from 18 countries, to change their shoes & clothes upon arrival at the plant, and to wash their hands immediately, in order to raise the percentage of good products.

You can easily understand therefore that a wafer manufacturing plant is more like a chemical laboratory than a electronics factory. In general, wafer manufacturing requires large quantities of water, electricity and chemicals. At the same time, the assembly line requires a relatively large work force. Overnight labour for the wafer process is moreover indispensable. And the assembly and inspection processes use such chemicals as organic solvents and radioactive substances like krypton 85.

Many assembly lines belonging to American and Japanese semiconductor companies are now located in Southeast Asia. In pursuit of good water quality and cheap labour, many semiconductor facilities are located in Kyushu (Japan's most southerly island). Japanese research and development facilities, however, are concentrated near Tokyo or in the USA.

A Comparative Study of Japan and USA Semiconductor Industries

Trade friction between semiconductor businesses is a typical economic issue dividing Japan and USA. The USA semiconductor industry consists in the main of 1, captive manufacturers like IBM, AT & T and Hewlett & Packard, and 2, specialized semiconductor manufacturers, for example, 170 companies in Silicon Valley. On the other hand, the main Japanese computer makers, like NEC, Fujitsu, Hitachi and Toshiba, themselves both manufacture semiconductors and sell them abroad. SIA, the Semiconductor Industry Association, is an organization of relatively small-scale semiconductor manufacturers in the USA.

The Japanese semiconductor industry has developed its share of the business mainly in the field of the memory chip LSI, such as DRAM (Dynamic Random Access Memory). On the other hand, the American semiconductor industry has specialized in the technologically more valuable fields of microprocessors, ASIC (Application Specific IC) and so on. Today, Japanese manufactures are paying a great deal of patent royalty for DRAM and microprocessors to US manufacturers, for example, Texas Instruments. The major US semiconductor manufacturers have developed their global strategies and have located their facilities in Europe, Asia and Japan. The market shares of the Japan and American semiconductor industries reflect these factors: in 1984, Japan's share in the USA market, including captive USA manufacturers, was 9.6%. On the other hand, the

USA's share in the Japanese market, including the shipment from USA companies in Japan and other countries, was 19.1%. At the same time, because of the semiconductor treaty between Japan and USA, the USA's share in Japan is expanding. The *direct* market share of the USA semiconductor business in Japan increased from 8.4% in 1986 to 20.2% in 1992. Therefore, we have to look carefully at the fact that, contrary to general belief, Japan has become an inroad.

It is more significant that the Japanese and USA semiconductor companies have developed commonly-agreed strategies of technology and marketing. It is also noteworthy that a multinational company like Texas Instruments has established "twin" factories in Japan and USA, developing common methods to raise the rate of good products, to keep down costs, to communicate information and circuit maps by communication satellite.

Since the research, development and manufacturing of semiconductors now operates on a global scale, citizens' environmental protection movements cannot cope with the situation without themselves having to develop worldwide "networks" to communicate their information.

4.2. Relationship between High-Tech and Environmental Problems

I have already pointed out that the relationship between high-technology and environmental problems focuses on high-technology like microelectronics and new material, while biotechnology develops on the basis of new sorts of substances: this is contrary to the saying, "the message is more important than the material". These substances, even if they have little value in themselves, have long-term and combined effects on human health which are not yet sufficiently clear. At the same time, it is very hard to dispose of some of these materials. Still more, the severe competition between companies accelerates high-technology related research & development. Since information about high-technology is restricted, protective environmental action tends to be delayed.

The Semiconductor Production Process and Environmental Problems

When I analyse the environmental aspects of semiconductor production processes, two problems come to the fore: 1, why do manufacturers use so many sorts of chemicals and gases, including toxic gas?; 2, is it possible to make the production of semiconductors safer?

Many of the processes used in semiconductor fabrication involve chemical reactions for micro-processing and multi-layering. These reactions include plasma reactions and ion implantation, where ion and plasma coexist and the free radical of high chemical activity generates itself.

Microelectronic device fabrication used to involve the use of photoresist chemicals before biologic scientists and physicians began to learn about their

toxicity. The toxicity of the plastic monomers is usually much greater than that of the finished polymers. For example, vinyl chloride monomers are much more toxic than polyvinyl chloride. Little is known of the toxicologic properties of the photoactive components.

The microscopic precision necessary for producing IC depends on several processes which utilize radio frequency and microwave radiation as well as x rays. Some investigators have wondered about the relative harmfulness of such radio frequency radiation. The severe competition between semiconductor companies stimulates new processes before related technology has been developed to monitor them. Hazardous materials are often used simply because they were the *first* to be used in the research laboratory.

4.3. The Material Balance of A Semiconductor Plant

How many materials that affect the environment do semiconductor factories in Japan use, for instance? Basing my analysis on *A Survey of IC Industry and the Environmental Protection* (1987), which includes a questionnaire to nationwide semiconductor plants (1985) and Inspection (10 plants), I should like to enumerate the chemicals which are used in each process and describe how they are treated and disposed.

Water Usage

During the summer of 1987, many semiconductor plants in the Tokyo area were forced to limit their operations because of a water shortage. Semiconductor fabrication uses a great deal of water for air conditioning and cleaning. Many plants pump up groundwater. According to the *Survey*, one semiconductor plant uses 1.6 million gallons on average per day (minimum 0.4 million gallons, maximum 4 million gallons per day). MITI's *Statistics of Industry, Lands and Water* (1991) reveals that one IC plant on average uses 2.7 million gallons per day. Maximum amounts are 10 times as great as minimum amounts. The amount of water used by each plant depends on the condition of the location.

Some plants like Texas Instruments, Miho (Ibaragi Pref.) and NMB (Nittetsu) Semiconductor, Tateyama (Chiba Pref.), implement a "closed system" of drainage. In spite of higher investment and running costs than usual, the "closed system" has some advantages: 1, more strict regulation of the water quality is required; 2, usage of too much water is difficult; 3, more hazardous materials are used in the process; 4, it offers a good impression of the plant.

4.4. Organic Solvent

According to the *Survey*, trichloroethylene — the organic solvent most extensively used in the wafer making process — amounts to 8.4 million pounds (51

plants) a year. 70% of the trichloroethylene is used for washing away photoresist; 30% is used for the cleaning of the chips & instruments. 20% of the input becomes exhaust gas, 78% of which is discharged without treatment. 80% of the input becomes liquid, two thirds of which is "sold" for recycling and one third of which is disposed of by "trader on commission". On the other hand, the amount of trichloroethane used is very small (410,000 pounds). 48% of the input becomes exhaust gas, 80% of which is discharged without treatment. 50% of the input becomes liquid, 30% of which is "sold" for recycling use, and 70% of which is disposed by "trader on commission".

Considerable amounts of organic solvent are therefore used during semiconductor fabrication. Inspections (10 plants) detected a relatively high density of organic solvent near exhausts without any treatment apparatus.

An investigation (1988) by the Environment Agency of Japan reported that air pollution by organic solvents is at a critical stage. Especially, tetrachloroethylene and carbon tetrachloride were detected at 37 points nationwide. The maximum detected levels of trichloroethylene, tetrachloroethylene and carbon tetrachloride are above the regulation level set by WHO. The Air Pollution Control Law of Japan, however, does not designate organic solvent as a toxic substance. Several options are open to semiconductor manufacturers to reduce these emissions. These can be divided into 3 major categories: 1, the addition of control equipment; 2, the modification of material reformulation process; 3, the improvement of manufacturing procedures. Emissions from positive photoresist operations are 1/10 those from negative photoresist operations.

Treatment of Exhaust Gas and Waste Disposal

As to the treatment of the exhaust gas itself, trichloroethylene is treated with a water scrubber (aeration apparatus); it is not very efficient, however. Activated carbon removes up to 90-95% of the trichloroethylene. Solid & liquid wastes of organic solvents and toxic gases are mainly disposed of by "trader on commission". Inspections (10 plants nationwide) detected trichloroethylene in the waste oil and arsenic in the vacuum pump oil & on clothes at the ion implantation process.

Near Tokyo, some cases of illegally dumped organic solvent waste have been found. Leakage from waste solvent transportation trucks is another problem. In February, 1985, in Ibaragi Prefecture a 212 gallons leakage of waste solvent from a truck polluted a rice field, and halted its operation.

4.5. Problems of Organic Solvent

Organic solvents are widely used not only by the semiconductor industry but also by laundries, for degreasing metal, and as painting solvent. These organic

solvents are trichloroethylene, tetrachloroethylene, trichloroethane and cellosolve (EGE). In the past, the primary concern about solvents focused on their acute irritating effects on mucous membranes, etc. More recently, attention has shifted onto their chronic, neurologic and neuropsychological effects, as well as onto their carcinogenicity and their harmful effects on human reproductive processes.

Since an air conditioner in a "clean room" gets rid of dust but not evaporated chemicals, it can circulate these chemicals within the plant, and thus expose the workers to recirculated solvent and chemicals.

Trichloroethylene

As the *Survey* shows, the percentage of trichloroethylene used in Japan is still high. As to its effects on the central nervous system, depression, dizziness, lack of coordination, loss of muscle control, drowsiness, fatigue, peripheral neuropathy, tremors, giddiness, anxiety, nausea, vomiting and behavioral changes have all occurred in animals exposed to concentrations as low as 9 ppm.

In Woburn, Massachusetts, as I have already noted, a group from the Harvard School of Public Health found a positive statistical association between access to water contaminated with trichloroethylene and the incidence rates of childhood leukemia. For people exposed to the solvent, a new theory stresses the need for attention to the role played by taking a shower and washing one's hands in addition to the monitoring of drinking water.

Tetrachloroethylene

When you walk past a laundry shop, you can smell a special odor, that of tetrachloroethylene, used in dry cleaning. The semiconductor industry also uses tetrachloroethylene. A recent epidemiological study of dry cleaning workers (1,711 persons) shows an excess of deaths from "other forms of heart disease" and "other disease of the liver" among dry cleaning workers with a history of exposure to organic solvent, regardless of personal habits. Since dry cleaning in Japan also uses petroleum solvents and 1,1,1-trichloroethane, we cannot attribute these disease to tetrachloroethylene only. Nevertheless, we have to pay attention to the results of this study.

1, 1, 1-Trichloroethane (Methylchloroform)

On our desks we keep bottles of white liquid which we use for correcting; this liquid includes 100% pure 1,1,1-trichloroethane. Since 1,1,1-trichloroethane is regarded as less harmful than trichloroethylene, Japanese industries have replaced trichloroethylene with 1,1,1-trichloroethane. As I remarked in the Chapter 1, however, 1,1,1-trichloroethane is suspected of causing birth defects. A group from the New Jersey Medical School investigated the relation-

ship between 1,1,1-trichloroethane exposure and the appearance of cardiovascular abnormalities in rats. Furthermore, 1,1,1-trichloroethane helps to deplete the ozone layer, although its level is not so high as that of CFCs (freon Gas). The reported release of 1,1,1-trichloroethane to the Californian environment has increased 10% in three years. This solvent is used widely in the aerospace, auto, metal products, electronics and chemical industries.

Glycol Ether (EGE)

The semiconductor industry also uses the glycol ether, cellosolve, as a photoresist. The State of California recently recommended that methoxyethanol and ethoxyethanol should be regarded as potential toxins on male and female reproductive organs after animal studies had demonstrated their sperm toxicity, embryotoxicity and teratogenesis. These effects occurred at levels close to the current permissible exposure levels (PELs). In Japan, too, the PELs of EGE have been lowered from 200 ppm to 5 ppm. The Japanese Association of Occupational Safety, Hygiene Investigation Center, has carried out animal studies on EGE; the results make clear the need for much stricter regulations than are at present in force.

4.6. Problems of CFCs

At Berkeley and Palo Alto, California, "containers for takeout" made with CFCs are banned. CFCs or Chlorofluorocarbons, which consist of chlorine, fluorine and carbons atoms, are nontoxic, inert and degreasing. Today, CFCs are used in refrigerators and air conditioners, as blowing agents to create foam in containers and cushions, as solvents to clean computer chips and as propellants in some aerosol cans. High-tech companies especially use a rapidly increasing amount of CFC-113. American electronics manufacturers consumed about 55.5 million pounds of CFC-113 in 1984, 37% of all that was produced that year. IBM was the biggest electronics user of CFCs in the world. For example, IBM's San Jose plant purchased more than 2.6 million pounds of CFC in 1987. When exposed to sunlight, the chlorine in CFCs can destroy ozone molecules in the stratosphere. Ozone molecules absorb most of the ultraviolet radiation that comes from the sun, while ultraviolet causes sunburn, some skin cancers and is effecting changes to the climate & within the earth's ecosystem.

Furthermore, each CFC molecule is 20,000 times as efficient at trapping heat as one molecule of CO₂. CFCs therefore augment the greenhouse effect. CFC molecules have a long-life, about 100 years. Their concentration in the air of Japan has risen 2.5 times in 7 years. In Japan, about half of the CFCs utilized are used for cleaning (mainly high-tech industry).

In September, 1987, the "Montreal Protocol" proposed a 35% net reduction

of CFC production worldwide by 1999. In 1992, representatives of 86 countries declared their intention to phase out their production and use of CFCs by the year 1995, it was also decided to phase out 1,1,1-trichloroethane by the year 1995.

4.7. Toxic Gas

Dangerous Toxic Gas

I mentioned in Chapter 2 that in March, 1988, three people were killed in New Jersey by silane gas. In Japan, as well, on the 2nd of October 1991, two people were killed by silane gas required for the CVD apparatus at Osaka University. The danger and toxicity of gases used in semiconductor fabrication come from their flammability, corrosiveness, explosiveness, suffocating-nature and direct toxicity.

As to flammability, for example, silane is a pyrophoric gas, which even 100% halone gas cannot extinguish. In Japan, in November, 1984, 22 pounds germane (GeH_4) exploded at Nippon Sanso, Kawasaki (Kanagawa Pref.) as the result of a decompositive reaction, while in December, 1989, an explosion probably caused by monosilane killed one person and injured three persons at a research & development facility belonging to Hitachi, Musashi (Tokyo).

In Japan, 17 cases of accidents (1976-1988) caused by toxic gas in the semiconductor industry have already been reported *officially* by the Ministry of Labour. About half of these cases involved death by suffocation after the inhalation of inert gases. Inert gases like nitrogen and argon are used as a balance gas. Suffocation is partly due to the mistaken belief that a "clean room" circulates air and that "nitrogen" means safety. Some places with a deficiency of oxygen have been found only after semiconductor plants started operating. As to toxicity, only one respiration of certain substances will cause deadly damage. Hydrides like arsine, stibine and germane cause severe hemolytic anemia with a

Table 5. Toxic Gases Classified by Their Dangerousness

Flammability	Germane, Arsine, Phosphine, Silane, Diborane, Dichlorosilane
Explosiveness	Hydrogen, Ethylene, Acetylene, Propane, Hydrogen Sulfide, Carbon Monoxide
Suffocation	Argon, Nitrogen, Carbon Dioxide
Toxicity	Arsine, Diborane, Phosphine, Silane, Boron Trifluoride, Ammonia, Carbon Monoxide, Hydrogen Sulfide, Chlorine, Hydrochloride, Boron Trichloride, Phosphorus Trichloride, Silicon Tetrachloride
Corrosiveness	Ammonia, Hydrochloride, Chlorine, Boron Trichloride, Phosphorus Trichloride, Phosphorus Pentachloride, Silicon, Tetrachloride
Stink	Dinitrogen Oxide, Hydrogen Sulfide, Chlorine, Ammonia, Hydrochloride, Boron Trifluoride

(*Semiconductor Gas Safety Data Book*, Science Forum Publisher, 1984 Edition)

peripheral blood smear that may show anisocytosis, red cell fragments, and ghost cells. It is reported that the proliferative response of human peripheral lymphocytes may be a useful indicator in the evaluation of the toxicity of arsenic, for instance, while workers at wafer processes have a relative enhancement of their proliferative response.

How can we handle gases safely? Mr. Hikaru Harada (Nippon Sanso) proposes "4 principles of safety" for handling gases: 1, exact knowledge of the nature of gas; 2, the use of safety apparatus; 3, the accurate operation of machinery; 4, safety training.

1. : "exact knowledge of the nature of gas" means that we should not use any sort of gas without an exact knowledge of the nature of each gas. It is noteworthy that harmfulness to human health depends on whether the element's form is either a simple substance, an oxide, or a hydride.
2. : "use of safety apparatus": it is necessary to reduce the number of connecting parts and thus the possibility of leakage, and to select fireproof & corrosion-proof material. For example, in the case of a fire at Miyazaki-Oki (Miyazaki Pref.), in 1982, pipelines made of vinyl chloride connected to a CVD (Chemical Vapor Deposition) apparatus were the cause of the fire. Some Japanese chemical manufacturers, who have recently commenced semiconductor gas fabrication, have tried to break into the market without installing sufficient pieces of safety apparatus, in an effort to keep down prices and reduce the safety control costs. In the USA, major chemical manufacturers are also beginning to operate in this way. A growing number of semiconductor companies use 100 percent phosphine in the doping process. This high concentration is not necessary, but is merely a convenience to avoid changing cylinders and thus to keep down costs, since cylinders of lower concentrations would be more expensive to run.

According to the *Report of Specialty Gas Usage* issued by Kanagawa Prefecture, Japan (61 plants, 1985), about half the plants have no special power sources for gas use, and over 60% of the plants keep cylinders on site. Small-scale factories handling only one~three sorts of gas have particular problems.

3. : "accurate operation of machinery". *The Survey on Toxicity and Use of Gases used by Semiconductor Fabrication* (1987, 76 plants) issued by the Ministry of Labour claims that 70% of the "near miss" accidents are due to a miss-operation, while 30% are due to insufficient inspection of the machines. Accidents related to the changing and transporting of metal cylinders offer an example: 1, mistaking safety valves for opening valves; 2, toxic gas leakage at the time of cylinder washing; 3, connecting cylinders

which have different container concentrations ; 4, the dropping of cylinders.

4. : "safety training" is therefore very important. But small-scale businesses and captive manufacturers (for example, watch makers) do not have enough means to do this.

In all cases, the semiconductor industry should seek to replace hazardous processes and materials with safer ones. In fact, some manufactures are trying to use safer processes. For example, silicon tetrachloride is now used instead of silane, organic arsenic is used instead of arsine, phosphorus chloride is used instead of phosphine.

Exposure to Dopant

Investigators from the National Institute of Occupational Safety and Health (U. S. NIOSH) have recently shown that low levels of dopant compounds are released from silicon wafers for several hours following ion implantation. This may account for the "odor problems" that workers often complain of.

Thus, for example, "Suspect Inhalation from Doctor First Report of Illness for Santa Clara and San Mateo Counties, October 1978- March 1980" (*Semiconductor Industry Study*, 1981, p.13) shows that the dopants are in the first rank as suspect causative agents. A "clean room" is in general well ventilated, but ventilation in certain localities within a room is not adequate.

Radiofrequency and Microwave Radiation

Today, many families use radiofrequency ranges (cooking stoves). Besides producing heat, however, radiofrequency has many biologic effects such as mutagenesis, carcinogenesis, reproductive disorders, growth and development of teratogenicity, ocular disturbances, neurologic & behavioral disorders and cardiovascular problems. Recently, the plasma process has become more common for removing coating (photoresist etc.) from wafers. Researchers in the USA surveyed four microelectronics manufacturing facilities and found up to 61% of the plasma etchers produced external radiofrequency (13.56 MHz) exposures in excess of recommended standards.

Potential Disaster

Although high-tech plants appear to be "lean", "smart" and "fireproof", semiconductor plants nevertheless use many sorts of toxic chemical at high temperatures & high-voltages. If there is a gas leak, a power failure or a machine stoppage, they therefore risk a big fire or a major disaster. If a "clean room" catches fire, it cannot receive pump-in water from outside if there are no windows. Air ventilation may circulate toxic gas. The concentration of apparatus

with toxic chemicals hinders efforts to extinguish fires. An unbelievable accident occurred one day when it was found impossible to get water to the fire. This happened at the Miyazaki-Oki LSI plant (Miyazaki Pref.) in October 1982. The origin of the fire, which killed one person, seemed to be a CVD (Chemical Vapor Deposition) apparatus.

4. 8. Gallium Arsenide

These days, we can watch a large scale video at a baseball stadium. This type of video uses a LED (Light Emitting Diode) made of gallium arsenide: and gallium arsenide has emerged as an alternative semiconductor material to silicon. Gallium arsenide's advantages over silicon are 1, high speed; 2, low power; 3, radiation and temperature resistance. Furthermore, a combination of gallium arsenide and aluminum gallium arsenide, HEMT (High Electron Mobility Transistor) has been developed as a high speed chip for a BS tuner. In Japan, some wafer makers like Sumitomo Denko, Mitsubishi Monsanto, and a few other device makers like Fujitsu and SONY are now manufacturing a gallium arsenide wafer.

A recent case study shows that extremely high levels of arsenic were found in the cut-off room of gallium arsenide, while high levels of arsenic were also found during LEC (Liquid Encapsulated Czochralski) cleaning operation. Other studies indicate that the dissolution of a gallium arsenide compound may occur *in vitro* and be associated *in vivo* with significant blood arsenic concentrations following intratracheal and oral administration. Respirable gallium arsenide dust in ingot and wafer fabrication may be considered a source of arsenic exposure. We have therefore to pay just as much attention to the components & products of gallium arsenide as to other materials.

4. 9. Economic Aspects of High-Tech Pollution

Needless to say, the competitive development of high-technology is a capitalist business activity, and the environmental problems caused by high-tech development therefore have an economic background. In my Book *The Economics of Environment and Technology* (Tokyo, Aoki Shoten Publisher, 1980), I have analysed the relationship between business activities and environmental problems. My main conclusion were these;

1. Because of the pursuit of profit and 'cost-down' by businesses, savings on environmental protection apparatus causes environmental disruption.
2. Severe competition for new brands & chemical developments within a limited time by big companies forces them to omit the installation of safety checks of new products.

3. Therefore, it becomes a matter of urgency to devise systems to control & monitor artificially created synthetic chemicals.
4. Making use of "free natural reserves" such as groundwater leads to the ruthless exploitation of natural resources.
5. Business companies, under social pressure to attend to environmental protection, try to recover profits by pursuing 'cost-down' by recycling & reduction of waste.

I would like to analyse high-tech pollution with relation to these factors.

First. Formerly, environmental questions used to deal with drains, exhaust gases, industrial waste, garbage, and so on. Recent focus on high-tech pollution shows, however, that leakage from underground solvent tanks has caused groundwater pollution. This phenomenon will not have happened by accident. Why are there so many leakages from plants? The problem seems to be that many underground tanks are made of fiberglass, which is susceptible to chemical corrosion and will crack under uneven ground pressure. As I mentioned in Chapter 3, in Silicon Valley, today, double containment and strict monitoring are implemented. It is therefore clear that cost savings on safety management such as pressure testing and waste treatment caused the leakages from underground tanks.

Second. New production methods, storage methods, the usage of many sorts of chemical can cause environmental problems. New high-tech products are developed one after another, and their production processes are constantly being changed. Chemicals used for these processes are also developed under conditions of "trade secrecy". These conditions necessitate a safety check system for new chemical products and the gathering and disclosure of data at the level of government & companies. Furthermore, the usage and storage of chemicals remains a problem. As I have already said, some chemical manufacturers who have newly entered into the business of semiconductor fabrication try to break into the market without equipping their factories with sufficient safety apparatuses, in an effort to keep down prices; this arises from a desire to reduce safety control costs in that industry. Small-scale business and captive manufacturers have not enough financial means to carry out "safety training" procedures.

Third. High-tech pollution abuses groundwater by pumping up vast amounts of water and contaminating the groundwater which remains in the ground. Since underground microbes dissolve and absorb pollutants, groundwater has formerly been regarded as safe, and the protection of groundwater was regarded as a secondary subject. However, the pollution of groundwater draws attention to the importance of groundwater as a drinking water resource. The protection of the quality of groundwater as well as its quantity becomes urgent. As I have already observed, one Japanese semiconductor plant uses on average

2.7 million gallons of water per day. This is because the industrial costs for groundwater are lower than those for surface water. However, because of the location of plants and the agreements for environmental protection made between plants and cities, some plants do not use groundwater (for example, Iwate-Toshiba Electronics, Iwate Pref.) and other plants adopt "closed systems" of drainage (for example, NMB (Nittetsu) Semiconductor, Tateyama, Chiba Pref.). Today, some plants are trying to recover organic solvents and CFCs as well as drainage. Under the pressure of regulations, citizens' movements and local agreements, semiconductor plants are trying to save materials & water with "closed systems".

Fourth. Problems are caused by those who try to "shuffle off" the duty of waste disposal. These problems are 1, soil & groundwater contamination created by drum recyclers; 2, groundwater pollution caused by leakage from the sewage drains of a special "recycle" trader of organic solvent; 3, pollution of landfill site by a "disposal" trader. According to data provided by the Japanese Ministry of International Trade and Industry, only 1.45% of the waste (about 7 billion pounds) produced in IC factories was reused in 1988. While high-tech companies may themselves keep clean, this may be because they transfer their duty to treat and dispose of waste to others, and this may, in turn, cause pollution beyond the boundaries of the high-tech industries. This practice is the result of trying to avoid paying for the cost of environmental protection. We have also to monitor and regulate this sort of practice.

5. High-Tech Pollution in Japan

5.1. Groundwater Pollution by Toshiba Components, Kimitsu

In 1984, a child whose parents lived close to groundwater was born with serious defects. During the summer of 1987 pond carp began to swell and die. These incidents were recorded in Kimitsu, Chiba Prefecture, where groundwater pollution by a semiconductor plant was found during the spring of 1987, yet was not made public until September, 1988. 43 wells were investigated; 10 of the wells were found to be contaminated by trichloroethylene in quantities over the regulation level set by WHO. These 10 wells included a well for drinking water, a municipal well (well #3) and the well for the municipal swimming pool.

The highest detected level of trichloroethylene was 10,000 ppb (October, 1988), which was 330 times the regulation level (30 ppb). The source of the pollution was Toshiba Components, Kimitsu, which is located beside the upper reaches of the groundwater stream. It is noteworthy that 1, the municipal well is contaminated by trichloroethylene, 2, the source of the pollution is a branch of the high-tech industry, and 3, the fact of groundwater pollution was not disclosed for a year and half.

The Japanese Type of High-Tech Pollution

We already know from our experience of high-tech pollution in Silicon Valley that "High-tech industry is not always clean". In Japan, however, despite the continuance of groundwater contamination, the relationship between groundwater pollution and high-tech industry has not, except in a few instances, yet become public knowledge.

The groundwater pollution at Kimitsu is a typical case of high-tech pollution; it is also an exemplary case of Japanese high-tech pollution: both the company and the local government "covered up" the outbreak of pollution. The experiences of severe environmental disruption in Japan during the 1960's should have brought to an end this type of "covering up" of pollution.

Pollution Source : Toshiba Components

The pollution source, Toshiba Components, Kimitsu (500 employees), is a manufacturer of commutating semiconductors, and uses trichloroethylene for cleaning. Toshiba Components, Kimitsu, shares 25% of the world market for commutating semiconductors for automobiles. According to an investigation carried out by Kimitsu City, Toshiba used as much as 4.20 million pounds of trichloroethylene from 1972 till 1988, half of which was not recovered. The manager of general affairs at Toshiba Components has said, "We have covered the tanks of trichloroethylene with concrete walls, and moved the pipeline above ground" (*Asahi Newspaper*, Chiba Edition, September 9, 1988). Although there were no underground tanks, leakage nonetheless occurred at the time of changing and transporting of waste trichloroethylene. Trichloroethylene has been detected even as deep as 180 feet beneath the plant site.

City's Investigation Specified the Source of the Pollution

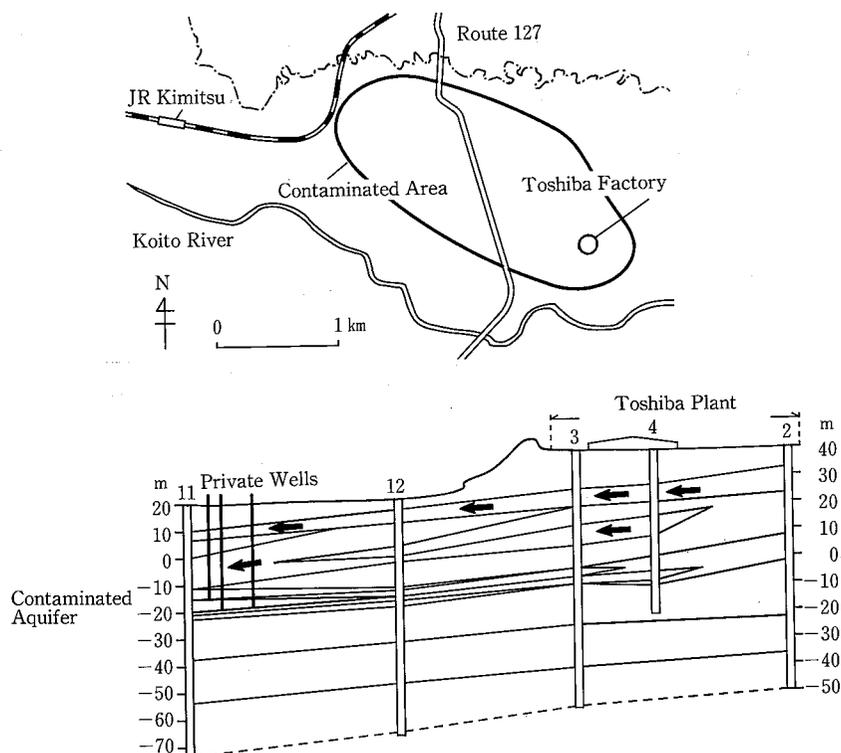
In January, 1989, a Kimitsu City investigation, cooperating with the Water Quality Protection Institute of Chiba Prefecture, with applications for detecting gas leakage, showed that Toshiba had polluted 70,000 cubic feet of soil to an average depth of 60-100 feet beneath the plant site.

This investigation is the most detailed survey of groundwater pollution in Japan. The investigation suggested that the causes of the pollution were 1, the dumping of waste trichloroethylene at the disposal site, and 2, the leakage of trichloroethylene during off-loading materials at the site.

Health Injury

Citizens in the neighborhood had complained of various health problems and required the City Hall to carry out a health survey. For instance, the child with a birth defect was hospitalized and other people have experienced miscarriages,

Fig. 2 Groundwater Pollution at Kimitsu City



heart disease and so on. In 1988, three aged persons died from unknown causes. A worker who dealt with waste trichloroethylene at the Toshiba plant was blinded when the liquid squirted into his eye. Toshiba changed over to the so-called "safer" trichloroethane in November, 1988. In Silicon Valley, however, trichloroethane itself is thought to have caused various birth defects. Toshiba's actions ought simply to be regarded as a "one round delay".

A Health Inquiry Task Force set up by Kimitsu City has already carried out a simple survey of citizens, but not yet a full epidemiological examination.

It is noteworthy that in 1984 the same Toshiba, Taishi (Hyogo Pref.), semiconductor plant caused serious groundwater pollution. At this time, the pollution reached the municipal water supply, and levels of contamination over the regulation standards were found in 128 wells (see below).

Pushed to act by a citizen's movement, in September, 1989, Kimitsu City and Toshiba drew up on an Agreement of Environmental Protection which includes items such as "safety management of chemicals", "citizens' inspection" and "trade secrets". Today Kimitsu City is pumping up the polluted wells and treating them with aeration apparatus. At the same time the City has changed the source of drinking water from wells to surface water. However, the THMs (trihalomethanes) levels of the surface water is still as much as 36 ppb, which is

higher than the trichloroethylene level of 5 ppb fixed for treated groundwater. This is because the regulation level of THMs is 100 ppb, while that of trichloroethylene is 30 ppb, according to the standards established by the Japanese Ministry of Health and Welfare.

5.2. Nationwide Groundwater Pollution in Japan

Early in 1983, a first-time Survey carried out by the Environment Agency showed that groundwater throughout Japan is polluted. According to the Land Agency, 23% of all drinking water depends on groundwater. Even the fountain called "meisui" near the foot of Mt. Fuji, famous for its good quality, is contaminated by organic solvent. Data published in 1988 reveals that 22 of Japan's 48 prefectures have detected pollution of groundwater. Further, the survey of 1989 shows that 112 of 359 wells (6 Pref.) include samples of cis-dichloroethylene, which is more harmful than trichloroethylene.

Since metal degreasing and dry cleaning operations as well as the semiconductor industry also use organic solvent, it is not clear that the high-tech industry is the sole cause of groundwater pollution. I have therefore had to analyse the survey of cities which house semiconductor plants (wafer process), and although I find that wells in Higashine (Yamagata Pref.), Aizu-Wakamatsu (Fukushima Pref.), Matsudo (Chiba Pref.), Kyoto, Yokkaichi (Shiga Pref.) are polluted by trichloroethylene, the relationship between the presence of a semiconductor plant and the pollution of wells remains unclear.

5.3. Toshiba, Taishi Plant

—The First Example of High-Tech Pollution—

Detection of Pollution

Ever since "Shotoku Taishi" (Prince Shotoku) ruled the area centuries ago, this city has been named "Taishi". Taishi, located to the west of Osaka, is known for its long history and temperate weather. The first case of high-tech pollution caused by a semiconductor plant in Japan occurred at Taishi. The source of the pollution was Toshiba, Taishi (1,200 employees). Opened in 1959, the company produces semiconductors and Braun tubes for TV. Today, it is a center for discrete type semiconductor manufacturing. Since this city has plentiful groundwater, people have always utilized the wells. In 1983, an investigation for THMs detected groundwater pollution. The municipal well for drinking water registered 407 ppb of trichloroethylene. 128 of 427 wells showed readings over the regulation level. At Woburn, Massachusetts, health injuries have been reported for levels of 267 ppb. Later, investigations by Taishi City and Hyogo Prefecture showed that the source of the pollution was located near building #407 of the Taishi plant. From 1970, Toshiba, Taishi, was using trichloroethylene for

the cleaning of semiconductors. From 1981 until 1983, the plant also used 264,000-660,000 gallons of groundwater per day.

The Cause of the Pollution

What caused the pollution near building #407? A detailed analysis carried out by Hyogo Prefecture reported that "building #407 was located near a tank of trichloroethylene" and that "soil contamination was due to problems of storage and usage of the tank." As for the removal of the contaminated soil, the investigator reported that "Since the groundwater spring lies 23 feet beneath the surface, it is difficult to dig out more contaminated soil." The report went on to say, "Hyogo Prefecture had previously directed Toshiba not to lay the facilities under the ground," and "Since the tank and pipeline have already been removed, it is difficult to investigate more accurately the cause of pollution." This report leads one to suppose that the tank of trichloroethylene had, in fact, been laid under the ground and that the leakage from the tank and pipe caused the pollution. It is also worth noting that the removal of the contaminated soil was stopped at a

Fig. 3 Groundwater Pollution at Taishi City (Trichloroethylene)

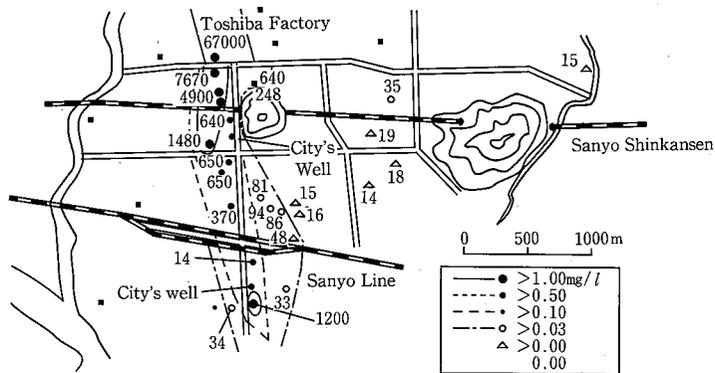
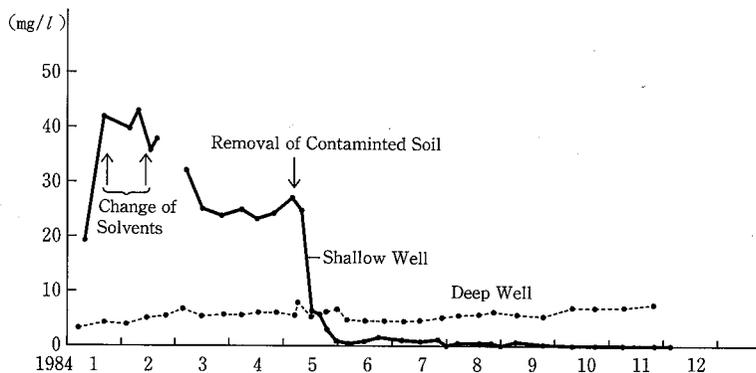


Fig. 4 Fluctuation of Contaminated Groundwater at Taishi City



depth of 23 feet. When we consider that at the Fairchild site, San Jose, the slurry wall goes down to a depth of 130 feet, Toshiba's action is simply not thorough enough. Although after the removal of the contaminated soil in May, 1984, the pollution level in the wells decreased, the contaminated soil that was not removed is still able to pollute wells located downstream of the groundwater. The contamination levels in deep wells (to a depth of 130-200 feet) are therefore gradually rising. (see the Fig.4) In 1988, the highest pollution levels in local wells measured 500-600 ppb. Without the removal of the contaminated soil to depths below 23 feet, groundwater pollution is bound to continue.

As for leakages from underground storage tanks, Canon, Kanuma (Tochigi Pref.), which manufactures lenses for copying machines and cameras, recently polluted waste water and soil with tetrachloroethylene (2.5 ppm in the soil). The leakage seems to have occurred from an underground storage tank used to contain tetrachloroethylene and the degradation of activated carbon used in the waste water treatment.

Action to Halt Pollution

Today at Taishi, after the aerating of the groundwater and treating it with activated carbon, drinking water again comes from the municipal wells. Private wells have been taken over as public water services. At the same time, Taishi City Council has discussed the safety of the water after treatment and air pollution caused by the aeration. Although Toshiba changed from trichloroethylene to trichloroethane in February, 1984, and attached an absorbing apparatus with activated carbon to each cleaning facility, trichloroethylene has nonetheless been detected in the surrounding wells (maximum 640 ppb), while trichloroethane is being detected at even higher levels than before.

Problems to Be Solved

The Agreement for Environmental Protection drawn up between Taishi City and Toshiba does not include special items to cover the use of groundwater and chemicals. Although Toshiba is required to report to the City the name of the chemicals it uses, the citizens are not permitted to know what these are. Since, in July, 1987, a fire broke out at a new building on the site, it has become necessary to treat the semiconductor facility as a chemical plant. Although liver complaints have been reported among local citizens, no health survey has been carried out.

Toshiba does not admit formal responsibility for the pollution; but the company pays the cost of water facilities as a "donation" (sic).

Although Hyogo Prefecture, who investigated the pollution, admitted the leakage from the underground tanks as a matter of fact, it nevertheless recorded

that the cause is "unknown"; it also failed to carry out a more detailed investigation of the contaminated soil or a health survey of the citizens. The owners of the private wells, uneasy and apprehensive, are now using groundwater for bathing and drinking. If the situation is left as it is, pollution from "unknown" causes is likely to continue for a long time and the local people will become "guinea pigs". Toshiba and Hyogo Prefecture will bear a heavy responsibility for any disasters that may happen.

5.4. Groundwater Pollution in Kumamoto

—A Critical Situation—

The State of the Pollution

Although many semiconductor plants like NEC and Mitsubishi are now located in Kumamoto, famous for the high quality of its groundwater, the Prefecture is beginning to suffer from serious groundwater pollution, and has had to modify its policy to develop a "Techno-Polis" (a high-tech industry area). Kumamoto City itself, which depends on its groundwater, has found that a great deal of its groundwater is now polluted by organic solvents. In 1982, a Survey of the Environmental Agency detected groundwater pollution in Kumamoto for the first time. In 1987, Kumamoto City detected contamination in 47 wells at levels that were over the regulation level. Pollution has already reached a depth of 300 feet. Even the source of the municipal well has been polluted by organic solvent, although the level of pollution is still below the regulation limit. Although the City Hall has said that most of the pollutants come from dry cleaning plants, the pathway of the pollution has not been thoroughly mapped.

The groundwater basin at the foot of Mt. Aso, Kumamoto Prefecture, is also polluted by organic solvent. According to a prefectural survey, the electronics industry uses the largest quantity of organic solvents (24 plants, 1,750,000 pounds in 1986). In 1986, the recovery rate of solvents by the electronics industry was 55%.

NEC and Mitsubishi, who use a wafer in their semiconductor production process, have no underground tanks and have already stopped using organic sol-

Table 6. Groundwater Pollution at the Groundwater Basin of Kumamoto

	Well Surveys	Wells Recording Excess
Wells at Plants	Tetrachloroethylene 40	5
	Trichloroethylene 40	1
Wells near Plant	Tetrachloroethylene 89	5
Drainage of Plant	Tetrachloroethylene 44	5

Time of Survey ; June-September 1987

Date Source ; Kumamoto Prefecture

vents. Nevertheless, problems remain at every facility.

NEC, Kyushu

NEC, Kyushu (Kumamoto City, 3,000 employees), is one of the biggest semiconductor plants in the world. NEC's strategy is to house "the main plants for research & development near Tokyo, while local plants are designed for mass production facilities".

NEC, Kyushu, is located in the southwest part of Kumamoto City. It was opened in 1970, has many related companies, and transports 60% of its products by air. NEC, Kyushu, once utilized organic solvents (about 66,000 pounds per month). The Agreement for Environmental Protection between Kumamoto City and NEC includes no regulations on underground pumping (790 million gallons per year) nor on the use of toxic chemicals. The gas storage facility of Toyoko Chemicals, located to the north of NEC, Kyushu, is next door to a kindergarten and clinic.

Fig. 5 Groundwater Basin at Kumamoto City

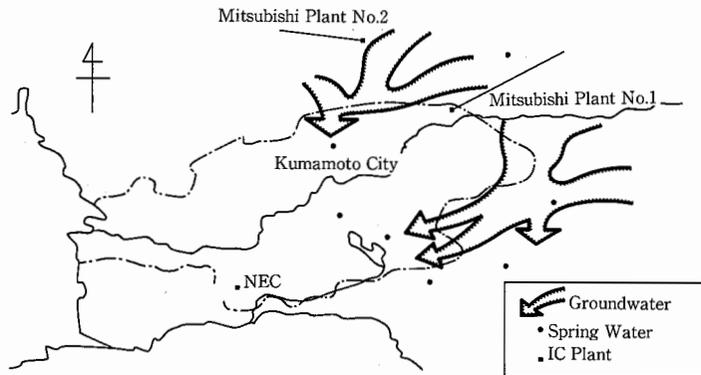
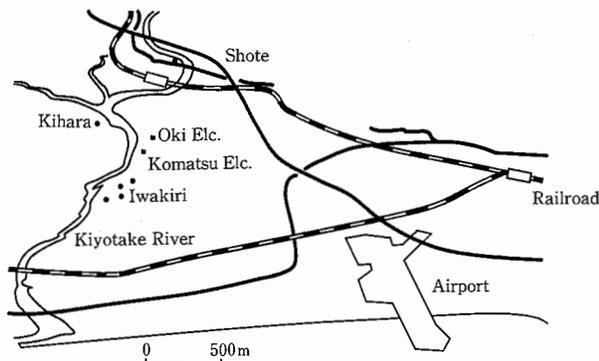


Fig. 6 Semiconductor Plant and Filtration Plant at Miyazaki City



Mitsubishi Kumamoto

Mitsubishi, Kumamoto (1,000 employees), is located in Nishi-Gohshi City, north of Kumamoto City, and is sited directly on the groundwater basin. According to the Regulation Section of the Environment Division, Kumamoto Prefecture, Mitsubishi has transferred its cleaning process to other companies, whose actions to ensure environmental protection are not known. The Agreement for Environmental Protection between Mitsubishi and Nishi-Gohshi City contains no items relating to groundwater protection and the safe use of chemicals.

An investigation carried out by Professor emeritus Masamoto Shimizu (December, 1986) detected 2.3 ppb and 2.6 ppb of trichloroethylene near drainage outlets at NEC and Mitsubishi respectively. It is therefore necessary to carry out thorough investigations into the pollution of groundwater in Kumamoto, and into the semiconductor facilities, especially into their use of toxic chemicals and their management of any subcontracting plants.

5.5. Miyazaki City Municipal Water Source is Located near the Drainage Outlets of Two Semiconductor Plants

The fire at Miyazaki-Oki (1,750 employees) in 1982 revealed that Miyazaki Prefecture (in Kyushu) had a semiconductor plant. Miyazaki City's municipal water sources are located near the drainage outlets of two semiconductor plants. The filtration plants at Shimokitakata and Tomiyoshi are located downstream of Kyushu-Fujitsu along the Ohyo River while the filtration plant at Iwakiri is located 1700 feet downstream of Miyazaki-Oki and Kyushu-Komatsu (wafer manufacturer) along the Kiyotake River.

The Degradation of the Source Water

The Kiyotake River has two filtration plants upstream and one, the Iwakiri filtration plant, downstream. These three plants use shallow wells (a depth of 20 feet) and river water under flows. Investigations carried out by the Japan Scientists Association, Miyazaki Branch, show that the presence of nitrate, chlorine ion, calcium, magnesium increased from 1980 till 1985. Especially after 1981, the differences between the water quality of the upstream water sources and those downstream (Iwakiri) increased markedly. So, too, did the nitrate ion, calcium ion, chlorine ion, calcium, magnesium and ph in the water at the Iwakiri filtration plant. Thus, since 1981, when the Miyazaki-Oki plant was opened, pollution of the Iwakiri filtration plant has increased. This cannot be just a coincidence. In the winter of 1985, the citizens took a sample of drainage water at Kyushu-Komatsu and had it analysed. 780 ppb of trichloroethane was detected. This was twice as much as the regulation level. We note that Mi-

yazaki-Oki (wafer process) and Kyushu-Komatsu (wafer manufacturing) are neighbors and that their drainage outlets together flow into the Kiyotake River. The Iwakiri filtration plant is located 1700 feet downstream.

New Agreement for Environmental Protection

Neither the Agreement for Environmental Protection drawn up between Kiyotake City and Miyazaki-Oki & Kyushu-Komatsu, nor the Agreement for Environmental Protection between Miyazaki City and Miyazaki-Oki has been made available to the public. In August, 1984, the Environment Agency issued a notice about the regulation of trichloroethylene etc., and the Agreements were subsequently revised, although not until 1986. The new Agreements include items such as 1, environmental protection plans; 2, chemicals; 3, organic solvents. Nevertheless, these new agreements are insufficient to forestall high-tech pollution. This is because 1, they treat only a number of the chemicals used by the semiconductor industry; 2, there is no limit set to the total amounts of chemicals that may be used, and 3, the industries are not required to recover chemicals completely.

An IC lead frame manufacturer plans to locate its facility at Takanabe City, north of Miyazaki City, the site of many oyster farms. Since the facility uses plating, drainage treatment will be a big problem. Kiyotake City exempted Miyazaki-Oki from fixed property taxation for three years, and the city therefore lost an important tax revenue. This policy of attracting such famous companies to one's city raises many questions. In the future, it will be necessary for Miyazaki-Oki and Kyushu-Komatsu to disclose their environmental data, and for the Cities to set up monitoring systems. It is also necessary to reconsider the location of filtration plants beside rivers into which drainage from semiconductor plants flows.

5.6. Groundwater Pollution along the Tama River

Because 60% of Tokyo's high-tech industries are concentrated along the Tama River, people call this locality "Tama High-Tech River". Residents near the Tama River use more groundwater than people in other areas in Tokyo. Here, too, the groundwater is polluted.

In October, 1982, Fuchu City in Tokyo detected a high density of trichloroethylene (930 ppb) in the municipal wells. The Water Supply Division of Tokyo City had already ordered the closing of the wells. In December, 1982, the Tokyo Environmental Protection Division disclosed its views about the nature and problems of the pollution;

"1. Although we have investigated 18 plants which use trichloroethylene, we

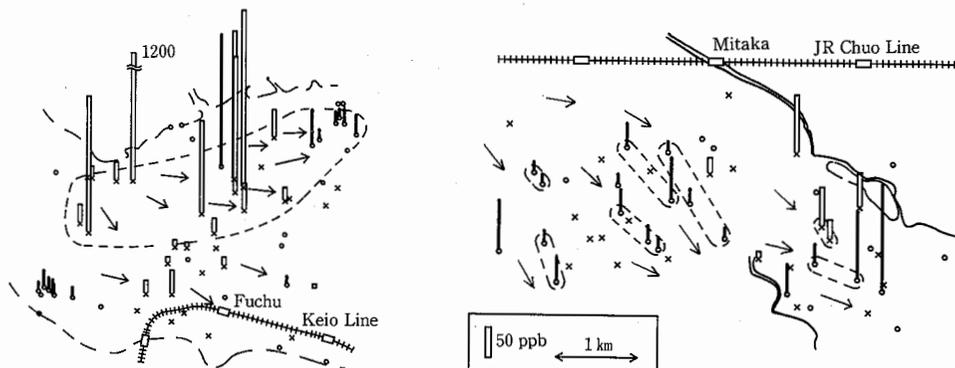
- cannot locate the cause of the pollution.
2. We have also investigated T-electronics, Fuchu, which uses much trichloroethylene and where there is a contaminated well (774 ppb), but we cannot specify the direct cause of the pollution.
 3. We have re-investigated 4 plants which dispose their drainage underground. As a result, we have finally found out that H-manufacturer used trichloroethylene before 1975. We also detected 1,760 ppb of trichloroethane at the disposal box.
 4. We cannot deny that H-manufacturer disposed trichloroethylene underground as a result of its working style. Further, the disposal of trichloroethane underground is not advisable. We therefore have ordered H-manufacturer to stop disposing of trichloroethane and to improve its drainage facilities." (The Tokyo Watch Committee of Pollution, *Bulletin*, No. 73, 1983)

T-electronics, Fuchu, is Toshiba, Fuchu, which manufactures and distributes not semiconductors, but electronics parts. According to the investigator, Toshiba had a special drainage system, but since its dry well had already been sealed off, the cause of the pollution was not established.

H-manufacturer is Hamai Manufacturer, sited next to the Toshiba plant, and it makes valves for LPG containers. We note that even at the time of the investigation (December, 1982), Hamai was disposing trichloroethane underground, although the Fairchild case in Silicon Valley had already been reported and was known in Japan.

Later investigations have shown that the groundwater pollution at Fuchu is wider and deeper than at any other site in the Tokyo area. According to a simulation of groundwater pollution at Fuchu City by the National Environment Institute, "the shallow well contamination has continuance", and "it takes many years for the polluted groundwater to move even 0.6 mile."

Fig. 7 Groundwater Pollution in Tokyo (Trichloroethylene)



Another case of groundwater pollution, at Mitaka City, Tokyo, seems to have been caused "by the direct disposal of solvent into old wells and dry wells", according to the investigator. Pollutants of organic solvent came from metal processing, printed circuit board manufacturing, automobile parts and dry cleaning.

Groundwater pollution has also been caused by leakage from sewage plants, where electronics components factories have disposed solvents. For example, in the early 1970's, at Komae City, Tokyo, the disposal of organic solvent through the sewage by camera and electronics parts plants, penetrated underground, and caused acute trichloroethylene poisoning of the workers at an underground sewage construction plant.

As early as 1974, the Tokyo Metropolitan Research Laboratory of Public Health had detected trichloroethylene and tetrachloroethylene in the groundwater. Groundwater pollution through sewage has also been recorded at a high-tech industry area near Boston, USA.

At Kawasaki City (Kanagawa Prefecture), on the opposite bank of the Tama River, the groundwater is also polluted. Kawasaki City houses many research & development centers for the semiconductor industry. According to the Environmental Protection Division of Kawasaki City, "the relationship between groundwater pollution and semiconductor related industries is not deniable, but it is difficult to specify the source of pollution" (*Asahi Newspaper*, Kanagawa Edition, October 27, 1988).

Many toxic chemicals have been detected in Kawasaki Bay. The environment Agency has detected dioxin (2,3,7,8-TCDD) in the mud of Tokyo Bay (2 ppt). In 1986, Kawasaki City carried out an environmental survey of chemicals used at four semiconductor plants (NEC, Toshiba, Fujitsu). The results, however, have not been made available to the public.

Since there are many possible sources of groundwater pollution along the Tama River, we can not necessarily call it "High-Tech Pollution". Nevertheless, the manufacture of electronics parts and printed circuit boards is related to the semiconductor industry, and Tokyo and Kanagawa Prefecture house many semiconductor research & development centers. In Kanagawa Prefecture, especially, where many high-tech industry are located, factories and private homes are found side by side. Recently at Sagami-hara City and Hadano City where many high-tech factories are located, Kanagawa Prefecture finds high concentration of contaminated groundwater. According to a *Report of Specialty Gas Usage* by Kanagawa Prefecture (61 plants, 1985), the number of plants using toxic gases like silane and phosphine has increased by three times in seven years. Many facilities have no special extinguishers nor power sources for gas use. In 1984, there was an explosion of germane gas at Nihon Sanso, Kawasaki.

Table 7. Production Amount of Organic Solvent (Million Pounds) in Japan

Year	Trichloroethylene	Tetrachloroethylene	Trichloroethane
1985	160	159	265
1986	157	154	281
1987	141	186	288
1988	154	213	305
1989	143	201	361
1990	125	184	408
1991	113	148	388
1992	135	139	369

Data: MITI, *Statistical Year Book of Chemical Industry*.

If we wish to fight high-tech pollution, we have to pay attention not only to groundwater contamination but also to chemical pollution in general.

6. How to Protect Our Environment

6.1. Legal Regulation of Chemicals

Production of Chemicals

So serious and everyday is chemical pollution that PCB has even been detected in a mother's milk. The present-day development and production of chemicals is so remarkable that the number of chemicals known to us has now reached eight million. About 70 thousand chemicals are used as general commodities. Every year about one thousand new chemical substances are generated.

One of the groups of chemicals that have caused groundwater pollution is the organochlorine chemicals. Organochlorine has a relatively higher toxicity than other chemicals. The Japanese "Chemical Substances Control Law" designated nine substances as specified chemicals (the first category: PCB, PCN, HCB, DDT, aldrin, endrin, dieldrin and chlordane etc). Recently, Japanese production of trichloroethane (a substitute for trichloroethylene) and tetrachloroethylene (a substance in CFCs) has increased; so, too, has dichlorobenzene (used as a pesticide). Organochlorine was originally produced to assist the disposal of chlorine as a by-product of the electrolysis of sodium hydroxide.

These chemicals penetrate the environment in many ways. *The Report of the Workshop on Practical Approaches for the Assessment of Environmental Exposure* published by the OECD, Environment Directorate (1986), has listed the sources of exposure:

- 1, point discharge to water from industrial sources;
- 2, release to water from municipal sewage treatment plants;
- 3, point source release to air;
- 4, release to air from disperse source;
- 5, direct deliberate application to soil;
- 6, landfill dis-

posal of wastes ; 7, incineration of wastes.

Revised Japanese Chemical Substances Control Law

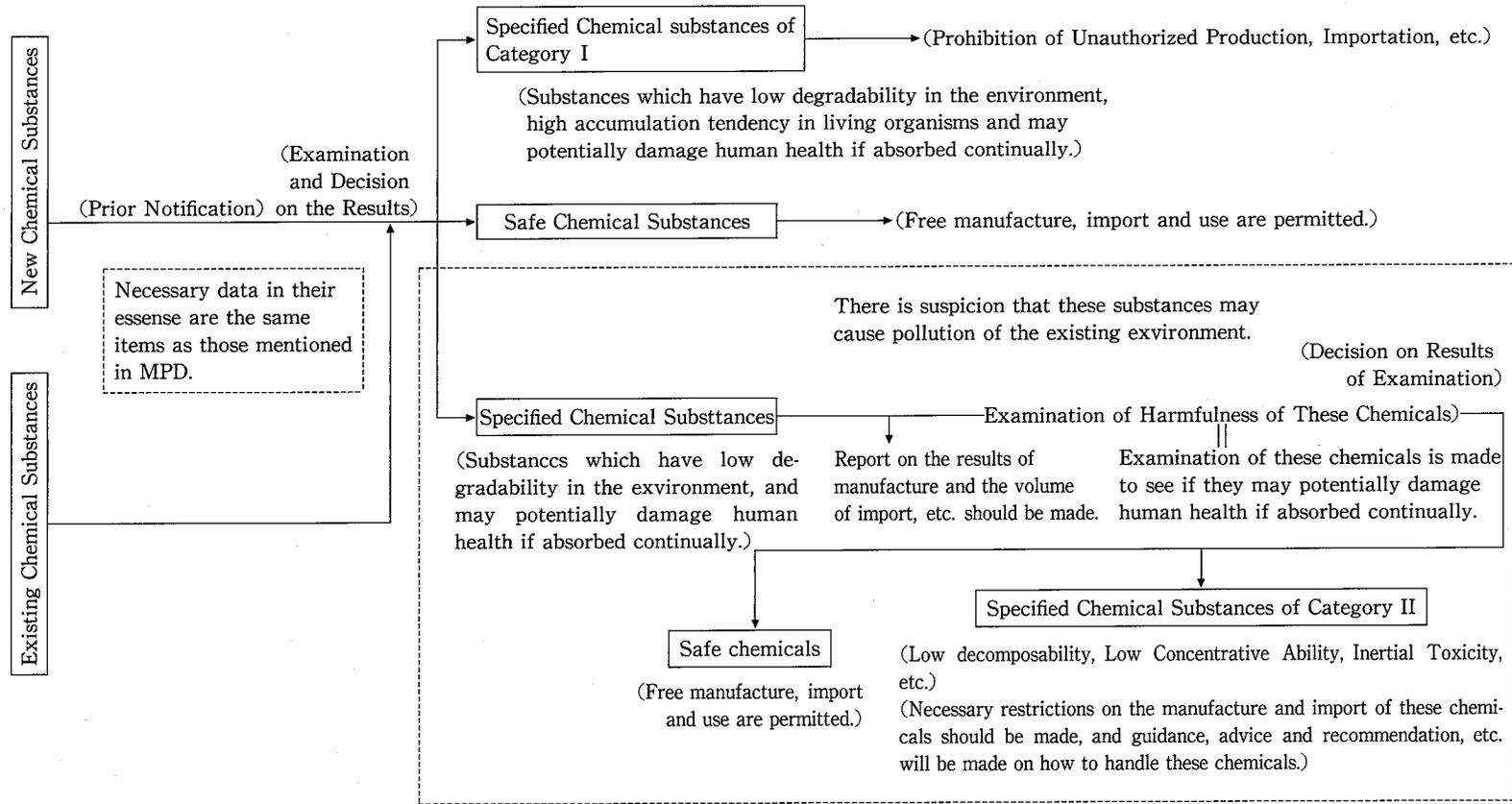
Although the Japanese government has now passed many laws to regulate pollution caused by the high-tech industry, these laws lack uniformity. In April, 1987, the Chemical Substances Control Law (The Law concerning the Examination and Regulation of Manufacture, etc., of Chemical Substances) was amended to cope with chemicals involved in high-tech pollution. This amended law requires the classification of a substance that is suspected of biological degradability and toxicity as a "specified chemical substance". If the harmfulness of this substance is confirmed, it is classified as "a second category of specified chemical substances", whose production and import must then be regulated. The Ministry of International Trade and Industry is mainly in charge of testing substances for biological degradability and the accumulation of chemicals in fish, while the Ministry of Health and Welfare tests their toxicity through the examination of animals. At the same time, the Environment Agency carries out studies and surveys of the state of chemical substances in the environment. The most important problem raised by the amended chemical substances control law is that even if an "specified chemical substance" is suspected of toxicity, its discharge into the environment is allowed, if the chemical is not dispersed over a "very wide area". Yet groundwater pollution by organic solvent is dangerous to human health, irrespective of its accumulation or dispersal. The amended law is not sufficiently stringent to cope with groundwater pollution, which was what triggered the revision in the first place. The environmental investigation of chemical substances by the Environment Agency detected 28 of 82 chemicals which the Ministry of International Trade and Industry has checked for "degradability" in their effect on the environment.

Since applications to use chemicals are made to both the Ministry of International Trade and Industry and the Ministry of Health and Welfare, chemicals data are gathered by both ministries. Such information should be made open to public inspection. In Japan, however, the results of the toxicity testing of pesticides registered at the Ministry of Agriculture and Fishery is not disclosed, because the data are regarded as the "property of the company".

In the USA, however, the "Emergency Planning and Community Right-to-Know Act of 1986" (SARA Title-III) is a very good guide, because it requires the owner of chemicals to open to the community knowledge of 1, emergency planning ; 2, a material safety data sheet ; 3, a list of extremely hazardous substances ; 4, an emergency and hazardous chemical inventory.

Groundwater pollution at Kimitsu City triggered the revision of the water pollution control law in 1989 : 1, organic solvents like trichloroethylene are in-

Fig. 8 Regulatory System under the Chemical Substances Control Law



Notes: The sign [] denotes the parts of major amendment made in the regulatory system under the Chemical Substances Control Law.
 MPD (Minimum Premarketing Set of Data) means those items for assessment of the minimum safety of chemicals before they are put on the market, which were recommended by the Council of OECD in 1982.
 Source: Environment Agency Government of Japan. (1990). *Quality of the Environment in Japan 1989*, Printing Bureau, Ministry of Finance, p. 112.

cluded among substances subject to the control of law; 2, penal regulations are added to clauses relating to the protection of groundwater.

Although the Ministry of International Trade and Industry designated trichloroethylene, tetrachloroethylene and carbon tetrachloride as falling within "the second category of a specified chemical substance", trichloroethane is not included in the list. In 1988, the Ministry of Labour issued a "guideline" for toxic gases used at semiconductor plants: 1, facilities for gas supply should be made of suitable material and be constructed to prevent gas leakage; 2, clean rooms should have adequate ventilation systems, ventilation times and emergency exits; 3, every piece of apparatus should have equipment designed to prevent gas leakage and electric shock; 4, during maintenance work, special attention should be paid to the control of toxic gas. This guideline was based on a survey of 76 plants and the issue of the guideline itself is appreciated. Nevertheless, the results of the survey are not open to the public and the revised safety standards for the use of toxic gas are not sufficiently clear.

As to organic solvent, the Ministry of Labour has revised the Occupational Safety and Health Law and designated total 47 organic solvents, 35 of which need to be labelled as toxic. The law also requires the examination of the workers' environment.

6.2. An Agreement for Environmental Protection which Requires Manufacturers to Submit Names of All Chemicals Used

— Kitakami City and Iwate-Toshiba-Electronics —

Iwate-Toshiba-Electronics

Kitakami City is located along the Kitakami River in Iwate Prefecture in the north-eastern part of Japan. Iwate-Toshiba-Electronics in Kitakami City has attracted the attention of other local governments, because Toshiba has signed an Agreement with Kitakami City for Environmental Protection; this includes the naming of chemical items used.

Iwate-Toshiba-Electronics (2,500 employees), which opened in 1973, began making semiconductors in 1984. Since Toshiba is within easy access of the Tohoku Highway and is able to tap abundant water and recruit a workforce, Iwate-Toshiba-Electronics has become a center of ASIC (Application Specific IC) production in eastern Japan. Because of the poor quality of the groundwater, Toshiba uses industrial water from the Kitakami River (2.6 million gallons per day).

The Agreement for Environmental Protection

The most significant aspect of the agreement for environmental protection between Kitakami City and Toshiba is that the second item orders Toshiba to

present data of chemicals used at the plant on request of the Kitakami City Authorities. The 5th item stipulates the prevention of groundwater pollution, while the 10th item authorizes the City's inspection of the plant. These items are appropriate for application to all semiconductor plants. Once Kitakami City had proposed to draw up agreements for environmental protection with 18 companies at the Industrial Park, the City concentrated on Toshiba's semiconductor plant; and a task force from the environmental protection committee of Kitakami City subsequently carried out research and a survey of Toshiba, Taishi, and presented a draft of an agreement to the Mayor of Kitakami.

Subject for Future Study

The actual agreement differs in significant ways from the draft: 1, what the draft defined as "measure and record" the emission of substances which are not under the control of the law becomes "separately consult"; 2, the draft proposed an "entrusted specialist" as a "member of the inspection committee", but the agreement deletes this item; 3, the agreement introduces a "trade secret" item (item 13). In fact, Kitakami City did not disclose the draft of the agreement, but kept it "secret", too.

The chairman of the task force, Professor Tatsuo Goto (Iwate University), says that since the item "separately consult" has the character of a "watching" item, the contents of the agreement itself will be decided by the power relationship between Kitakami City and Toshiba. Later on, in September, 1987, the parties agreed on a memorandum that Toshiba will independently report the result of measurements of 22 toxic chemicals (drainage once per month or per four months, air twice per year). Among 22 toxic chemicals that are unregulated by laws six substances have to be drained: phosphorus, nitrogen, boron, silicon, carbon tetrachloride, xylene; and seven substances are emitted as exhaust: fluorine, hydrogen chloride, phosphorus, boron, carbon tetrachloride, xylene, arsenic. The City itself can inspect organic solvent. Toshiba has already changed over to CFCs. Although the City had carried out three inspections by September, 1987, the standards of regulation and conditions for waste disposal trading were still not clear.

Iwate-Toshiba-Electronics started the production of CCD (Charge Coupled Device) in 1987 and ASIC in 1988. In 1990, the production level doubled while the numbers of part time jobs had been increasing. The building up of a "watching system" for the environment and strict safety training systems are therefore more than ever required.

Local governments should employ special staff responsible for watching high-tech "secrets", and the national government should strengthen its regulations on toxic chemicals.

6.3. An Agreement for Environmental Protection Including a "Closed Drainage System" and "Toxic Gas Regulation"

— Tateyama City and NMB (Nittetsu) Semiconductor —

Location of Semiconductor Plant

Tateyama, located at the edge of the Bohsoh Peninsula, is an agricultural and fishery area, with few factories. In April, 1984, however, a plan for a semiconductor plant was proposed. At that time, because of the boom in the semiconductor business, NMB, a manufacturer of ball bearings, was searching for a site for a semiconductor plant. NMB planned to make 256 K DRAM under license from Inmos (UK).

Since Tateyama is near Tokyo and has a good environment, NMB chose Tateyama as its candidate. And as Chiba Prefecture was particularly eager to attract high-tech industries they confirmed approval of the plan within only three months (August 1984).

The most difficult issue, however, has turned out to be the pumping up of groundwater. Since the groundwater dried up as a result of military use at the time of World War II, this area has no large groundwater basin. In addition, the municipal well and an agricultural pond are located near the site of the plant. Citizens living near the site therefore opposed the plan, and NMB nearly gave up the idea.

Since, at the same time, "High-tech pollution in Silicon Valley" was also being reported in Japan, the City Council discussed this problem and strict regulations were required.

Contents of Agreement for Environmental Protection

In Japan, today, about 220 agreements for environmental protection between local governments and semiconductor plants, research & development centers have been drawn up. Only 10% of these agreements, though, deal with chemicals which are not already regulated by law. Among them, the agreement for environmental protection between Tateyama City and NMB semiconductor (January 1985) may act as a model, because it includes a "closed drainage system" and a "toxic gas regulation".

This agreement was based on an agreement drawn up between Miho village (Ibaragi Pref.) and Texas Instruments, Japan. The amount of groundwater pumped up was reduced from 800,000 gallons per day to 160,000 gallons. A "closed drainage system", which uses water only for miscellaneous purposes and evaporation, was adopted. Waste chemicals have to be extracted and disposed of as industrial waste.

Although a "closed system" (Organo Corp.) costs 4,500 million yen (about \$30 million, total investment 30,000 million yen, about \$200 million), it is neces-

Table 8 Environmental Protection Plan of NMB Semiconductor (1985)

Industrial Waste

	Source of Generation	Form	Amount/Year
Sludge	Water treatment	Sludge	2.6 mil pounds
Waste Plastics	Production process	Solid	53000 pounds
Sulfuric Acid	Resist	Dense Liquid	904000 pounds
Nitric Acid	Diffusion	Dense Liquid	102000 pounds
Ammonia	Diffusion	Dense Liquid	33000 pounds
Fluohydric Acid	Etching	Dense Liquid	550000 pounds
Organic Solvent	Resist	Liquid	64000 pounds
Developer	Resist	Liquid	260000 pounds

Amount of Use

	Process	Amount/Month
Sulfuric Acid	Etching	5000 gallons
White Phosphorus	Ion Implantation	1100 pounds
Ammonia	CVD	13359 gallons
Hydrogen Fluoride	Etching	1900 gallons
Acetone		666 pounds
Isopropyl Alcohol		444 pounds
Metallic Arsenic	Ion Implantation	8.8 ounce

sary to take such special measures to protect the environment.

22 toxic chemicals have emission standards based on those set by ACGIH (American Conference of Governmental Industrial Hygienists). A "watching system", however, is only self-monitoring of the plant by the plant.

Recently, the NMB (Nittetsu) semiconductor company started the production of 4 Mega DRAM and pumped up the maximum limit of groundwater that had been modified to 320,000 gallons per day. It thus becomes necessary for the citizens and city to set up a regular & continuous "watching system".

The example of Tateyama City shows that as the city and citizens did not originally want to attract a semiconductor plant, they have been able to take a strong position and insist on strict regulations. We must, therefore, once again question the "Regional Development Policy" of attracting plants to rural or apparently suitable sites.

6. 4. To Forestall High-Tech Pollution

When I look at a high-tech plant operation from the backyard, I see that high-tech facilities use and store many sorts of toxic chemical and gas in on-site storage tanks and cylinders. This is my impression during field research of high-tech pollution in Japan and USA.

Fig. 9 Drainage Closed System at NMB Semiconductor

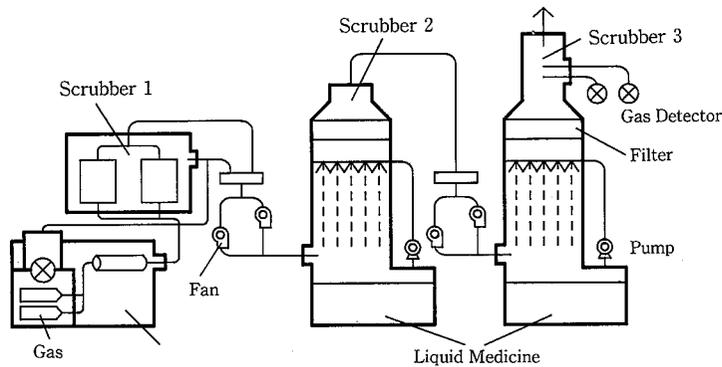
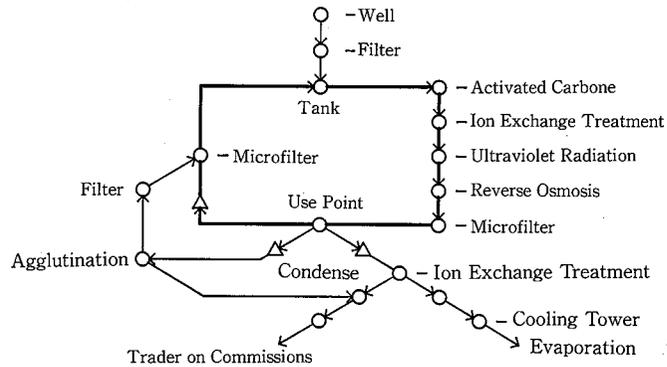


Fig. 10 Process Gas Treatment

When I visit such places, I notice that many sorts of high-tech pollution and agreements for environmental protection between cities and semiconductor plants have been drawn up. We have to pay attention to what they express in common, rather than their variety.

First. An uncontrolled "High-Tech Industry" is an essentially dangerous process. We should note, too, that factories which manufacture watches, commutator and electric automobile parts, which at first sight are not related to high-technology, sometimes fabricate semiconductors and therefore use organic solvents and toxic chemicals. If local government and citizens plan to attract factories, it is indispensable to know what they manufacture and how the plant will be used. Needless to say, it is not only necessary for the local government to draw up an agreement for environmental protection, but also for the agreement to include specific regulations regarding toxic chemicals. In cases where "regional development policy" aims to attract factories, local government and the citizens tend to be submissive. Now that, as a last resort to vitalise local economies, high-tech industry is welcomed from all quarters, this need becomes

more than ever important.

Second. Groundwater pollution and the disposal of toxic chemicals have reached an emergency level. In Japan, despite the continuation of groundwater contamination, the analysis of causes and routes is too protracted. In the USA, before the clean up began, much time and money was spent on the research into the causes and routes of pollution. If the investigation is inadequate, pollution will only grow worse, and the delay in taking action will cause even greater damage and even higher costs.

Japan has many legal problems to solve. In Japan there are only 11 substances which are regarded as harmful to human health (CN, R-Hg, Or-P, Cd, Pb, Cr, As, Hg, PCB, Trichloroethylene, Tetrachloroethylene). Even the Basel Convention on the control of transboundary movement of hazardous waste and their disposal designated only 47 substances. On the other hand, in the USA, SARA has listed 406 hazardous substances (1988), while CERCLA listed 721 hazardous substances (1988). Japanese regulations on waste disposal in the sea are also inadequate. Nor are regulations on organic solvents and CFCs anything like strict enough. If we fail to control each chemical until "accumulation" in the environment has been confirmed, or if we say that the suspicion that a product is "carcinogenic" is not sufficient reason to regulate its use, we are, in fact, approving "experiments on the human body" on a very large-scale. It is high time for us to remember the lessons we ought to have learned from the Minamata Disease.

Third. Information about chemicals used as materials or industrial commodities should be collected, centralized and disclosed to the public. Citizens are anxious about what is done at factories and how it is done. Yet as businesses themselves are so nervous about "high-tech", they try to keep the details "secret", which is common sense in a ruthless business world. In this respect, the US legal system and the citizens' movement of the "Right-to-know" offer a model. At the same time, the government should change its policy that "data about chemicals are the property of the companies". This is necessary because the use of these chemicals mostly affects the public. It is a matter of urgency to set up legal systems that control the whole process of manufacturing, circulation and disposal of industrial chemicals.

Last. To cope with high-tech pollution, local governments should have a right to "watch" and should strengthen citizens' involvement. Although "high-tech" is somehow difficult to understand, local government and citizens should nevertheless analyse and reconsider the policy of attracting companies, to forestall high-tech pollution. In some cases, local governments tend to blanket all environmental information, because the partial release of information would only make citizens uneasy. Yet, if the citizens come to know of the situation later,

their anxiety and confusion will be much greater. Early feedback from citizens would be helpful for the taking of initial all-round measures.

Because of the recent trade friction problem, the safety standards fixed for commodities imposed by each country have been criticized as forming a non-tariff-barrier. Because of the competition between countries, information about chemicals tends to be kept secret and investment on safety is thus saved. Confrontation between nations then tends to be stirred up. It is high time that we should move beyond national borders and the restrictions imposed by individual companies, and that all the citizens of the world should be able to exchange information, especially where it concerns safety and health.

Professor of Economics, Hokkaido University

References

Chapter 1.

1. Dapson, S. C. *et al.* (1984). "Effect of Methyl Chloroform on Cardiovascular Development in Rats." *Teratology*. Vol. 29, No. 2, p. 25A.
2. Epidemiological Studies Section, California Department of Health Services. (1985). *Pregnancy Outcomes in Santa Clara County 1980-1982*.
3. Lagakos, S. W. *et al.* (1986). "An Analysis of Contaminated Well Water and Health Effects in Woburn, Massachusetts." *Journal of the American Statistical Association*. Vol. 81, No. 395, pp. 583-596.
4. Epidemiological Studies and Surveillance Section, California Department of Health Services. (1988). *Pregnancy Outcomes in Santa Clara County 1980-1985*.
5. Byers, V. S. *et al.* (1988). "Association between Clinical Symptoms and Lymphocyte Abnormalities in a Population with Chronic Domestic Exposure to Industrial Solvent-Contaminated Domestic Water Supply and a High Incidence of Leukaemia." *Cancer Immunology Immunotherapy*. Vol. 27, No. 1, pp. 77-81.
6. National Institute of Environmental Health Sciences. (1987). *National Toxicology Program, Developmental Toxicity Evaluation of 1, 1, 1-Trichloroethane Administered to CD Rats. Final Report*. NTP-87-220.
7. Wrensch, M. *et al.* (1990). "Hydrogeologic Assessment of Exposure to Solvent-Contaminated Drinking Water: Pregnancy Outcomes in Relation to Exposure." *Archives of Environmental Health*. Vol. 45, No. 4, pp. 210-216.
8. Swan, S. H. *et al.* (1992). "Is Drinking Water Related to Spontaneous Abortion? Reviewing the Evidence from the California Department of Health Services Studies." *Epidemiology*. Vol. 3. No. 2, pp. 83-93.

Chapter 2.

1. State of California, Department of Industrial Relations, Division of Occupational Safety and Health, Task Force on the Electronics Industry. (1981). *Semiconductor Industry Study*.
2. U. S. E. P. A. (1987). *Santa Clara Valley Integrated Environmental Management Project, Stage Two Report*.
3. U. S. 99th Congress, First Session. (November 16, 1985). *Hearing before the Subcommittee on Investigations and Oversight of the Committee on Public Works and Transportation, House of Representatives*. San Jose.

4. Patrick, R. *et al.* (1987). *Groundwater Contamination in the United States*. 2nd ed. (Philadelphia : University of Pennsylvania Press).
5. Gassert, T. (1985). *Health Hazards in Electronics. A Handbook*, (Hong Kong : Asia Monitor Resource Center).
6. LaDou, J., Ed. (1986). *Occupational Medicine, The Microelectronics Industry, State of the Art Review*. Vol. 1, No. 1, (Philadelphia : Hanley & Belfus, Inc.).
7. Robbins, P. *et al.* (1989). "Summary of Occupational Injuries and Illnesses in the Semiconductor Industry for 1980-1985." in *Hazard Assessment and Control Technology in Semiconductor Manufacturing*. pp. 3-16, (Chelsea, MI : Lewis Publishers, Inc.).
8. Pastides, H. *et al.* (1988). "Spontaneous Abortion and General Illness Symptoms among Semiconductor Manufacturers." *Journal of Occupational Medicine*. Vol. 30, No. 7, pp. 543-551.
9. Lin, V.K. (1986). "Health, Women's Work and Industrialization: Semiconductor Workers in Singapore and Malaysia." (Ph. D. Thesis, University of California, Berkeley, CA).
10. Division of Occupational/Environmental Medicine and Epidemiology, University of California at Davis. (1992). *Epidemiologic Study of Reproductive and Other Health Effects among Workers Employed in the Manufacture of Semiconductors, Final Report to the Semiconductor Industry Association*.

Chapter 3.

1. Kizer, K.W. *et al.* (1988). "Sound Science in the Implementation of Public Policy." *JAMA*. Vol. 260, No. 7, pp. 951-955.
2. Pease, W. S. (1988). "Environmental Pollution and Cancer in California : Evaluating the significance of risks under Proposition 65." (Master Thesis, University of California, Berkeley, CA).
3. U. S. EPA. (1987). *Waste Minimization, Environmental Quality with Economic Benefits*.
4. U. S. EPA. (1988). *The Citizens' Guidance Manual for The Technical Assistance Grant Program*.

Chapter 4.

1. Association of Industry and Environment. (1986). *Report of High-Tech Industry and Environment*, [in Japanese].
2. KHN (Society for Safety of Condensed Gas). (1987). *Reference Book for Safety of Specialty Gas*, [in Japanese].
3. Science Forum. (1987). *Manual Book for Safety of High-Technology*, [in Japanese].
4. Brown, H. S. *et al.* (1984). "The Role of Skin Absorption as a Route of Exposure for Volatile Organic Compounds(VOCs) in Drinking Water." *American Journal of Public Health*. Vol. 74, No. 5, pp. 479-484.
5. Environmental Agency. (1988). *Biological Effect of IC Industry Material*, [In Japanese].
6. Izumi, K. (1987). *Dreadful CFCs Pollution*, (Tokyo, Godo Shuppan) [in Japanese].
7. KHK. (1985). *Report about an Accident of Specialty Gas*, [in Japanese].
8. Ungers, L. J. *et al.* (1985). "Release of Arsenic from Semiconductor Wafers." *American Industrial Hygiene Association Journal*. Vol. 46, No. 8, pp. 416-420.
9. Ken'mochi. K. (1986). *High-Tech Disaster*, (Tokyo, Nippon Hyoronsha) [in Japanese].
10. Yoshida, T. *et al.* (1987). "The Enhancement of the Proliferative Response of Peripheral Blood Lymphocytes of Workers in Semiconductor Plant." *Industrial Health*. Vol. 25, No. 1, pp. 24-33.
11. Webb, D. R. *et al.* (1984). "In Vitro Solubility and In Vivo Toxicity of Gallium Arsenide." *Toxicology and Applied Pharmacology*. Vol. 76, No. 1, pp. 96-104.

12. Environment Agency. (1987). *Reference Book of Gallium and Environment*, [in Japanese].
13. Lenihan, K. L. *et al.* (1989). "Assessment of Exposures in Gallium Arsenide Processing: A Case Study," in *Hazard Assessment and Control Technology in Semiconductor Manufacturing*. pp. 285-294, (Chelsea, MI: Lewis Publishers, Inc.).

Chapter 5

1. Nakasugi, O. (1984). "Groundwater Pollution by Organochloride." *Kikan Kankyo Kenkyu (Quarterly Journal of Environment Study)*, [in Japanese]. No. 52, pp. 125-135.
2. Yamada, K. (March/April/June/August, 1985). "Warning from Groundwater." *Gijyutsu to Ningen (Technology and Man)*, [in Japanese].
3. Suzuki, S. (1988). "Groundwater Pollution in Kumamoto City." Kumamoto Shoka University, *Sangyo Keiei Kenkyu (Study of Industry and Economy)*, [in Japanese]. Vol. 6, pp. 37-60.
4. Yamaguchi, H. (1972). "Acute Trichloroethylene Poisoning at Work by Shield Method." *Safety Engineering*, [in Japanese]. Vol. 11, No. 4, pp. 209-212.
5. Morita, M. *et al.* (1974). "An Investigation Analytical Method and Evaluation of Organic Matters." *Annual Report of Tokyo Metropolitan Research Laboratory of Public Health*, [in Japanese]. Vol. 25, pp. 399-403.

Chapter 6

1. Environmental Agency. (1987). *Study of Basic Information about Toxic Chemicals*, [in Japanese].
2. Oikawa, K. (1987). *Profile 100 of Hazardous and Toxic Chemicals in High-Tech Industry*, (Tokyo, Maruzen) [in Japanese].
3. Kinki Legal Profession. (1988). *Dangerous Groundwater Pollution*, [in Japanese].